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Final Independent External Peer Review Report Supplemental Major Rehabilitation Evaluation Report for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee



Prepared by
Battelle Memorial Institute

Prepared for
Department of the Army
U.S. Army Corps of Engineers
Risk Management Center
for the Nashville District

Contract No. W912HQ-10-D-0002
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by

Battelle
505 King Avenue
Columbus, OH 43201

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EXECUTIVE SUMMARY

Project Background and Purpose

Center Hill Dam is currently a U.S. Army Corps of Engineers (USACE) Dam Safety Action Classification I (DSAC I) dam, in DeKalb County, Tennessee. A Major Rehabilitation Evaluation Report (MRER) for Center Hill Dam was approved in 2006, and construction began in 2008. A baseline risk assessment was done in 2010 through 2012 to document post-construction risks for elements already completed or in construction. The risk assessment incorporates both new data (subsurface exploration obtained during construction) and risk-informed policies and procedures implemented after the original report was approved. Resulting changes to the scope of the rehabilitation effort include a reduction in barrier wall and grouting and the construction of a roller compacted concrete (RCC) reinforcing berm at the saddle dam (in lieu of a barrier wall and grout curtain). A Supplemental MRER, published in June 2013, includes the risk assessment and documents the changes to the project scope, including National Environmental Policy Act (NEPA) documentation and a real estate plan.

The Supplemental MRER was conducted in accordance with USACE Engineer Regulation (ER) 1110-2-1156, *Dam Safety Policy and Procedures*. Because Center Hill is a DSAC I dam (categorized as “Urgent and Compelling”), the Nashville District, in coordination with the USACE’s Lakes and Rivers Division, USACE Headquarters, and the Risk Management Center Director, has continued design of the RCC berm at the saddle dam concurrent with processing and approval of the Supplemental MRER. This will hasten the construction of the final protective measures and minimize project cost increases and schedule delays. Since the saddle dam RCC berm is already in the design phase, a Type II Independent External Peer Review (IEPR) (Safety Assurance Review [SAR]) is also under way.

Center Hill Reservoir is about 50 miles east of Nashville, Tennessee, and about 7 miles south of Interstate 40. The dam is in north-central DeKalb County, Tennessee. It impounds the Caney Fork River, a tributary of the Cumberland River, 26.6 river miles upstream of their confluence. The total Center Hill drainage area is 2,174 square miles. Because the average slope of the reservoir is over 3 feet per mile, the 18,000-acre lake is prone to rapid water-level rises. The total storage area exceeds 2 million acre-feet. The reservoir provides flood risk reduction, navigation, hydropower, recreation, water supply, and water quality benefits. The dam contains three hydropower units with a combined capacity of 135,000 kilowatts.

Center Hill Dam is a 248-foot high combination concrete-earthen embankment dam with foundation seepage issues stemming from original construction flaws. The embankment portion of the dam was placed directly on a mature karst limestone with little to no foundation treatment.

Outside the narrow core trench, existing alluvial and residual soils were left in place. Further adding to the risk are solution-widened joint sets that are parallel and perpendicular to the dam.

The main components of the 2006-approved MRER remediation plan are: (1) comprehensive foundation grouting, and (2) concrete cutoff walls into the foundation of the main dam and saddle dam embankments. The first major construction was the 2008 to 2010 grouting of the main dam embankment, the groin area, and the left rim. A barrier wall contract was awarded in 2011 for the main dam embankment.

Independent External Peer Review Process

USACE is conducting an IEPR of the Supplemental Major Rehabilitation Evaluation Report for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee (hereinafter Center Hill Dam Supplemental MRER). As a 501(c)(3) non-profit science and technology organization, Battelle is independent, is free from conflicts of interest (COIs), and meets the requirements for an Outside Eligible Organization (OEO) per guidance described in USACE (2012a). Battelle has experience in establishing and administering peer review panels for USACE and was engaged to coordinate the IEPR of the Center Hill Dam Supplemental MRER. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses. The IEPR was external to the agency and conducted following USACE and Office of Management and Budget (OMB) guidance described in USACE (2012a) and OMB (2004). This final report describes the IEPR process, describes the panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel (the Panel).

Based on the technical content of the Center Hill Dam Supplemental MRER and the overall scope of the project, Battelle identified candidates for the IEPR Panel in the following key technical areas: geotechnical engineering, engineering geology, hydraulic and hydrology engineering, economics/planning, and environmental planner/NEPA impact assessment. Five panel members were selected for the IEPR. USACE was given the list of candidate panel members, but Battelle made the final selection of the Panel.

The Panel received an electronic version of the 852 pages of Center Hill Dam Supplemental MRER documents, along with a charge that solicited comments on specific sections of the documents to be reviewed. USACE prepared the charge questions following guidance provided in USACE (2012a) and OMB (2004), which were included in the draft and final Work Plans.

The USACE Project Delivery Team (PDT) briefed the Panel and Battelle during an in-person kickoff meeting to discuss the Center Hill Dam project. The meeting was held on August 23, 2013, at the USACE Center Hill Dam Resource Manager's Shop Facility in DeKalb County, east of Nashville, Tennessee. All five panel members and one Battelle staff member attended this meeting and the subsequent site visit. As part of this meeting, USACE led Battelle and the Panel on a tour of the Center Hill Dam site. The tour included the a visit to the base of the saddle dam, the site of the proposed RCC berm, the fuse plug emergency spillway section on top of the saddle dam embankment, and the area downstream of the concrete main dam and main dam embankment. In addition, a Battelle-facilitated mid-review teleconference was held on August 29, 2013, to allow the Panel to ask USACE clarifying questions regarding the project. Other than

the kickoff meeting/site visit and mid-review teleconference, there was no direct communication between the Panel and USACE during the peer review process. The Panel produced individual comments in response to the charge questions.

IEPR panel members reviewed the Center Hill Dam Supplemental MRER documents individually. The panel members then met via teleconference with Battelle to review key technical comments, discuss charge questions for which there were conflicting responses, and reach agreement on the Final Panel Comments to be provided to USACE. Each Final Panel Comment was documented using a four-part format consisting of: (1) a comment statement; (2) the basis for the comment; (3) the significance of the comment (high, medium, or low); and (4) recommendations on how to resolve the comment. Overall, 12 Final Panel Comments were identified and documented. Of these, two were identified as having high significance, six had medium significance, and four had low significance.

Results of the Independent External Peer Review

The panel members agreed among themselves on their “assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used” (USACE, 2012a; p. D-4) in the Center Hill Dam Supplemental MRER review documents. Table ES-1 lists the Final Panel Comment statements by level of significance. The full text of the Final Panel Comments is presented in Appendix A of this report. The following summarizes the Panel’s findings.

Based on the Panel’s review, the report is well constructed to support a plan of action that would allow the Center Hill Dam to be reclassified from USACE’s DSAC I rating to a DSAC IV. The documents demonstrate that the project has had fundamental problems due to the original construction and that USACE has taken steps to address the problems in a timely and effective manner by developing solutions that are likely to be generally effective at minimum cost. The Panel agreed that USACE used appropriate methods and models in its analysis and provided adequate detail in describing the processes followed throughout the project. While the Panel deemed the report comprehensive with robust documentation in many areas, it identified areas of inconsistencies attributed to recent updates to the report and a few areas where additional clarification is warranted. The Panel is also concerned that given the numerous updates supplied during the review, the changes made during the review may not be consistently applied throughout the document.

Engineering – USACE has done a very good job of identifying and describing the root cause of all problems at Center Hill Dam (i.e., the presence of karst). The review documents use water pressure test results, boring logs, construction photos, dye test results, breakouts, connections, and lack of refusal during grouting operations, and locations of water seeps, springs, and leaks to better understand the karst behavior at the project site. The Panel also found Appendix G to contain a great deal of crucial information. Panel members found it especially helpful that USACE used all previous records and data to understand the geology, cost features, grouting, and interactions. The major issue noted by the Panel concerns the performance of the erodible fuse plug (i.e., whether it will fail as designed), and the implications if it does not fail within 30 minutes or sufficiently fast enough to prevent other issues from arising. The consequences of

the plug not failing within the designed 30 minutes or sufficiently fast enough to prevent other issues from arising is not addressed in the document provided. Premature failure of the fuse plug is only partially addressed in the document provided. These issues can be readily addressed by describing the fuse plug failure process over time, providing the results of the sensitivity analysis, and further exploring the impacts of dismissed potential failure modes (PFMs) in the Supplemental MRER.

The Panel is also concerned about the assumed increase in frictional strength along monolith contacts and other internal surfaces due to concrete expansion associated with alkali-aggregate reaction (AAR). The Panel is concerned that the assumed increase in frictional strength, not supported by any quantitative data, may not exist and therefore reduce the overall safety of the project and may have resulted in the elimination of a PFM or require additional mitigation measures at the main dam. The Panel suggests that further clarification about the assumptions regarding AAR and its applicability to PFMs 19A and 18B be provided to help address this concern. In addition, PFMs 6, 8, and 10 may have been dismissed prematurely, thereby affecting which remediation alternative is selected, and could therefore affect project benefits. This issue could be easily addressed by reviewing these PFMs to determine if one or more should be more fully developed.

Economics – The Panel believes that the summary of the event tree analysis for the significant failure modes and the alternatives that USACE has provided in the Center Hill Dam Supplemental MRER strengthens the understanding of the project. Furthermore, Appendix K provides a thorough presentation of costs regarding this dam safety project. However, the Panel has some concern about the left rim grout curtain and the right rim seepage. Since cost is neither constant nor predictable, the Panel believes that USACE should further investigate the costs for these two abutments. The Panel also notes that the definition of PFM 16 is inconsistent between the Supplemental MRER main report and Appendix B.

The accuracy of the reported remaining benefit-cost ratio could not be verified because it is unclear whether assumptions associated with remediation of the saddle dam or the barrier wall were used to generate the remaining benefits. The Supplemental MRER would benefit from a list of the assumptions used. It is also unclear whether the economic analysis has taken into consideration the annualized benefits of power and water supplied by the Center Hill Dam in relation to the annualized cost of the most likely alternative. Including information for the basis for using payment agreements instead of the costs incurred by the consumer for alternative water and power supply would provide clarification to the Supplemental MRER economic analysis.

Environmental – The Panel recognizes that the Supplemental MRER, while concisely written, is thorough and comprehensive; however, as recognized in the document, the environmental documentation is not quite complete. The potential effects of climate change on the tentatively selected plan are not considered, including potential effects on the Probable Maximum Flood (PMF) and reservoir elevation. This issue can be addressed by (1) describing the potential effects of climate change and how these potential effects were considered during the plan formulation process, and (2) revising the probability of failure if the reservoir stage versus probability function changes as a result of new calculations considering climate change parameters.

Resolution on treatment of the contaminated area where used timbers were formerly stored needs to be addressed.

Several topics customarily discussed in NEPA documentation were not included in the environmental summary of the Center Hill Dam Supplemental MRER or in the environmental assessment (EA). This can be addressed by including a brief discussion of construction effects and a mention of negative findings for potential federally or state-listed karst species. In other instances, some topics (sinkhole repairs, left rim stabilization, dam safety clearing, and weir repairs) either have incomplete descriptions or are still referenced, even though they are no longer part of the tentatively selected plan.

Plan Formulation – The Panel found that the plan formulation process is easy to follow and that the assumptions, methodologies, and results provide a well-reasoned and systematic basis for selecting the tentatively selected plan. It is apparent that a great deal of work has been expended regarding agency coordination and public communication; however, a summary of this outreach is not included and may be viewed as having been overlooked. In addition, outlining the agency and public communications that have occurred to date would strengthen the Supplemental MRER.

Table ES-1. Overview of 12 Final Panel Comments Identified by the Center Hill Dam Supplemental MRER IEPR Panel

No.	Final Panel Comment
Significance – High	
1	Uncertainty exists regarding whether the Center Hill Dam's erodible fuse plug will fail within 30 minutes, as designed.
2	The assumption that the alkali-aggregate reaction (AAR) increases normal stress on monolith contacts or other surfaces within the monoliths (and therefore adds to surface frictional resistance) is not supported by quantitative data.
Significance – Medium	
3	Several potential failure modes (PFMs) may have been dismissed prematurely, thereby potentially affecting project benefits.
4	The system response probabilities for Potential Failure Modes (PFMs) 7A, 7B, 7C, and 7D and their relationship to PFM 7 are not clearly presented in the documentation, and the choice of PFM 7C over 7D is not fully supported.
5	Apparent discrepancies in different sets of the dam breach modeling information and inconsistencies in the level of detail between different analyses made it difficult to assess the dam breach model.
6	The project documentation does not account for the possibility that additional seeps could develop in the groin area and impact the main dam embankment.
7	The effects of climate change on the Probable Maximum Flood (PMF) and the magnitude of the reservoir elevation have not been evaluated.
8	The assumption that upper and lower leaks in the right rim are primarily due to solution channels along the bedding planes is not valid.

Table ES-1. Overview of 12 Final Panel Comments Identified by the Center Hill Dam Supplemental MRER IEPR Panel (continued)

No.	Final Panel Comment
Significance – Low	
9	Several topics customarily addressed to comply with the National Environmental Policy Act (NEPA) either are not discussed in the project documentation or received minimal discussion, and some sections of the environmental assessment (EA) refer to measures that are no longer part of the tentatively selected plan.
10	It is unclear whether the economic analysis has taken into consideration the annualized benefits of power and water supply from the Center Hill Dam in relation to the annualized cost of the most likely alternative.
11	It is not clear what approach will be used to cap or restore an area of hazardous materials that leached from treated timber formerly stored on the site.
12	A detailed correlation between discontinuity orientations and known seepage pathways (karst features) has not been established.

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Appendix A.Final Panel Comments on the Center Hill Dam Supplemental MRER

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LIST OF ACRONYMS

AAR	Alkali-Aggregate Reaction
ASCE	American Society of Civil Engineers
ATR	Agency Technical Review
BA	Biological Assessment
COI	Conflict of Interest
DrChecks	Design Review and Checking System
DSAC	Dam Safety Action Classification
EA	Environmental Assessment
EC	Engineer Circular
EIS	Environmental Impact Statement
EM	Engineer Manual
EP	Engineer Pamphlet
ER	Engineer Regulation
ERDC	Engineer Research and Development Center
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
H&H	Hydraulic and Hydrology
HEC-FIA	Hydrologic Engineering Center-Flood Impact Analysis
HEC-HMS	Hydrologic Engineering Center-Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center-River Analysis System
IDF	Inflow Design Flood
IEPR	Independent External Peer Review
IWR	Institute of Water Resources
LiDAR	Light Detection and Ranging
MnDNR	Minnesota Department of Natural Resources
MRER	Major Rehabilitation Evaluation Report
NEPA	National Environmental Policy Act
OEO	Outside Eligible Organization
OMB	Office of Management and Budget

PDT	Project Delivery Team
PFM	Potential Failure Mode
PMF	Probable Maximum Flood
RCC	Roller Compacted Concrete
SAME	Society of American Military Engineers
SAR	Safety Assurance Review
SPT	Standard Penetration Test
TDR	Time-Domain Reflectometer
USACE	United States Army Corps of Engineers

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1. INTRODUCTION

Center Hill Dam is currently a U.S. Army Corps of Engineers (USACE) Dam Safety Action Classification I (DSAC I) dam, in DeKalb County, Tennessee. A Major Rehabilitation Evaluation Report (MRER) for Center Hill Dam was approved in 2006, and construction began in 2008. A baseline risk assessment was done in 2010 through 2012 to document post-construction risks for elements already completed or in construction. The risk assessment incorporates both new data (subsurface exploration obtained during construction) and risk-informed policies and procedures implemented after the original report was approved. Resulting changes to the scope of the rehabilitation effort include a reduction in barrier wall and grouting and the construction of a roller compacted concrete (RCC) reinforcing berm at the saddle dam (in lieu of a barrier wall and grout curtain). A Supplemental MRER, published in June 2013, includes the risk assessment and documents the changes to the project scope, including National Environmental Policy Act (NEPA) documentation and a real estate plan.

The Supplemental MRER was conducted in accordance with USACE Engineer Regulation (ER) 1110-2-1156, *Dam Safety Policy and Procedures*. Because Center Hill is a DSAC I dam (categorized as “Urgent and Compelling”), the Nashville District, in coordination with the USACE’s Lakes and Rivers Division, USACE Headquarters, and the Risk Management Center Director, has continued design of the RCC berm at the saddle dam concurrent with processing and approval of the Supplemental MRER. This will hasten the construction of the final protective measures and minimize project cost increases and schedule delays. Since the saddle dam RCC berm is already in the design phase, a Type II Independent External Peer Review (IEPR) (Safety Assurance Review [SAR]) is also under way.

Center Hill Reservoir is about 50 miles east of Nashville, Tennessee, and about 7 miles south of Interstate 40. The dam is in north-central DeKalb County, Tennessee. It impounds the Caney Fork River, a tributary of the Cumberland River, 26.6 river miles upstream of their confluence. The total Center Hill drainage area is 2,174 square miles. Because the average slope of the reservoir is over 3 feet per mile, the 18,000-acre lake is prone to rapid water-level rises. The total storage area exceeds 2 million acre-feet. The reservoir provides flood risk reduction, navigation, hydropower, recreation, water supply, and water quality benefits. The dam contains three hydropower units with a combined capacity of 135,000 kilowatts.

Center Hill Dam is a 248-foot high combination concrete-earthen embankment dam with foundation seepage issues stemming from original construction flaws. The embankment portion of the dam was placed directly on a mature karst limestone with little to no foundation treatment. Outside the narrow core trench, existing alluvial and residual soils were left in place. Further adding to the risk are solution-widened joint sets that are parallel and perpendicular to the dam.

The main components of the 2006-approved MRER remediation plan are (1) comprehensive foundation grouting, and (2) concrete cutoff walls into the foundation of the main dam and saddle dam embankments. The first major construction was the 2008 to 2010 grouting of the main dam embankment, the groin area, and the left rim. A barrier wall contract was awarded in 2011 for the main dam embankment.

The objective of the work described here was to conduct an IEPR of the *Supplemental Major Rehabilitation Evaluation Report for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee* (hereinafter Center Hill Dam Supplemental MRER) in accordance with procedures described in the Department of the Army, USACE Engineer Circular (EC) *Civil Works Review* (EC 1165-2-214) (USACE, 2012a) and Office of Management and Budget (OMB) bulletin *Final Information Quality Bulletin for Peer Review* (OMB, 2004). Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses.

This final report details the IEPR process, describes the IEPR panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel on the existing environmental, economic, and engineering analyses contained in the Center Hill Dam Supplemental MRER. The full text of the Final Panel Comments is presented in Appendix A.

2. PURPOSE OF THE IEPR

To ensure that USACE documents are supported by the best scientific and technical information, USACE has implemented a peer review process that uses IEPR to complement the Agency Technical Review (ATR), as described in USACE (2012a).

For the purpose of this IEPR, USACE has been directed by Congress to evaluate USACE dams for safety assurance and seepage/stability correction. IEPR provides an independent assessment of the economic, engineering, and environmental analysis of the project study. In particular, the IEPR addresses the technical soundness of the project study's assumptions, methods, analyses, and calculations and identifies the need for additional data or analyses to make a good decision regarding implementation of alternatives and recommendations.

In this case, the IEPR of the Center Hill Dam Supplemental MRER was conducted and managed using contract support from Battelle, which is an Outside Eligible Organization (OEO) (as defined by EC No. 1165-2-214). Battelle, a 501(c)(3) organization under the U.S. Internal Revenue Code, has experience conducting IEPRs for USACE.

3. METHODS

This section describes the method followed in selecting the members for the IEPR Panel (the Panel) and in planning and conducting the IEPR. The IEPR was conducted following procedures described by USACE (2012a) and in accordance with OMB (2004) guidance. Supplemental guidance on evaluation for conflicts of interest (COIs) was obtained from the *Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports* (The National Academies, 2003).

3.1 Planning and Schedule

At the beginning of the Period of Performance, Battelle held a kick-off meeting with USACE to review the preliminary/suggested schedule, discuss the IEPR process, and address any questions regarding the scope (e.g., clarify expertise areas needed for panel members). Any revisions to the schedule were submitted as part of the final Work Plan. In addition, 16 charge questions were

provided by USACE and included in the draft and final Work Plans. The final charge also included general guidance for the Panel on the conduct of the peer review (provided in Appendix B of this final report).

Table 1 presents the schedule followed in executing the IEPR. Due dates for milestones and deliverables are based on the award/effective date of August 1, 2013. The review documents were provided by USACE on August 9, 2013. Note that the work items listed in Task 7 occur after the submission of this report. Battelle will enter the 12 Final Panel Comments developed by the Panel into USACE's Design Review and Checking System (DrChecks), a Web-based software system for documenting and sharing comments on reports and design documents, so that USACE can review and respond to them. USACE will provide responses (Evaluator Responses) to the Final Panel Comments, and the Panel will respond (BackCheck Responses) to the Evaluator Responses. All USACE and Panel responses will be documented by Battelle. Battelle will provide USACE and the Panel a pdf printout of all DrChecks entries, through comment closeout, as a final deliverable and record of the IEPR results.

Table 1. Center Hill Dam Supplemental MRER IEPR Schedule

Task	Action	Due Date
1 & 3	Award/Effective Date	8/1/2013
	Review documents available	8/9/2013
	Battelle submits draft Work Plan and Charge ^a	8/8/2013
	USACE provides comments on draft Work Plan	8/13/2013
	Battelle submits final Work Plan and Charge	8/15/2013
2	Battelle requests input from USACE on the COI questionnaire	8/6/2013
	USACE provides comments on COI questionnaire	8/8/2013
	Battelle submits list of selected panel members ^a	8/12/2013
	USACE confirms the Panel has no COIs	8/13/2013
	Battelle completes subcontracts for panel members	8/16/2013
4	Battelle convenes kick-off meeting with USACE	8/9/2013
	Battelle sends review documents to Panel	8/19/2013
	Battelle convenes Panel kick-off meeting	8/20/2013
	Battelle convenes USACE/Panel kick-off meeting and site visit	8/23/2013
5	Panel members complete their individual reviews	9/3/2013
	Battelle provides Panel merged individual comments and talking points for Panel Review Teleconference	9/5/2013
	Battelle convenes Panel Review Teleconference	9/5/2013
	Panel members provide draft Final Panel Comments to Battelle	9/11/2013
	Battelle finalizes Final Panel Comments	9/17/2013

Table 1. Center Hill Dam Supplemental MRER IEPR Schedule (continued)

Task	Action	Due Date
6	Battelle submits Final IEPR Report to USACE ^a	9/25/2013
7 ^b	Battelle convenes teleconference with USACE to review the post-Final Panel Comment response process	9/27/2013
	USACE provides draft Project Delivery Team (PDT) Evaluator Responses to Battelle	10/2/2013
	Battelle convenes teleconference with Panel and USACE to discuss Final Panel Comments and draft responses	10/9/2013
	USACE inputs final PDT Evaluator Responses in DrChecks	10/11/2013
	Battelle inputs the Panel's BackCheck Responses in DrChecks	10/18/2013
	Battelle submits pdf printout of DrChecks project file ^a	10/18/2013
	Project Closeout	12/2/2013

^a Deliverable.

^b Task 7 occurs after the submission of this report.

3.2 Identification and Selection of IEPR Panel Members

The candidates for the Panel were evaluated based on their technical expertise in the following key areas: geotechnical engineering, engineering geology, hydraulic and hydrology (H&H) engineering, economics/planning, and environmental planner/ NEPA impact assessment. These areas correspond to the technical content of the Center Hill Dam Supplemental MRER and the overall scope of the Center Hill Dam project.

To identify candidate panel members, Battelle reviewed the credentials of the experts in Battelle's Peer Reviewer Database, sought recommendations from colleagues, contacted former panel members, and conducted targeted Internet searches. Battelle evaluated these candidate panel members in terms of their technical expertise and potential COIs. Of these candidates, Battelle chose the most qualified individuals, confirmed their interest and availability, and ultimately selected five experts for the final Panel.

The five selected reviewers constituted the final Panel. The remaining candidates were not proposed for a variety of reasons, including lack of availability, disclosed COIs, or lack of the precise technical expertise required.

The candidates were screened for the following potential exclusion criteria or COIs.¹ These COI questions were intended to serve as a means of disclosure and to better characterize a candidate's

¹ Battelle evaluated whether scientists in universities and consulting firms that are receiving USACE-funding have sufficient independence from USACE to be appropriate peer reviewers. See OMB (2004, p. 18), "...when a scientist is awarded a government research grant through an investigator-initiated, peer-reviewed competition, there generally should be no question as to that scientist's ability to offer independent scientific advice to the agency on other projects. This contrasts, for example, to a situation in which a scientist has a consulting or contractual arrangement with the agency or office sponsoring a peer review. Likewise, when the agency and a researcher work together (e.g., through a cooperative agreement) to design or implement a study, there is less independence from the agency. Furthermore, if a scientist has repeatedly served as a reviewer for the same agency, some may question whether that scientist is sufficiently independent from the agency to be employed as a peer reviewer on agency-sponsored projects."

employment history and background. Providing a positive response to a COI screening question did not automatically preclude a candidate from serving on the Panel. For example, participation in previous USACE technical peer review committees and other technical review panel experience was included as a COI screening question. A positive response to this question could be considered a benefit.

- Previous and/or current involvement by you or your firm² in the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- Previous and/or current involvement by you or your firm² in dam safety or flood risk management projects in the Caney Fork River, DeKalb County, Tennessee
- Previous and/or current involvement by you or your firm² in projects related to the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- Previous and/or current involvement by you or your firm² in the conceptual or actual design, construction, or operation and maintenance in projects related to the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- Current employment by USACE.
- Previous and/or current involvement with paid or unpaid expert testimony related to the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- Previous and/or current employment or affiliation with the Federal Energy Regulatory Commission (FERC); Tennessee Department of Transportation; or Tennessee Wildlife Resources Agency (for pay or pro bono).
- Past, current, or future interests or involvements (financial or otherwise) by you, your spouse or children related to the Caney Fork River, DeKalb County, Tennessee.
- Current personal involvement with other USACE projects, including whether involvement was to author any manuals or guidance documents for USACE. If yes, provide titles of documents or description of project, dates, and location (USACE district, division, Headquarters, Engineer Research and Development Center [ERDC], etc.), and position/role. Please highlight and discuss in greater detail any projects that are specifically with the Nashville District.
- Previous or current involvement with the development or testing of models that will be used for or in support of the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee project.
- Current firm² involvement with other USACE projects, specifically those projects/contracts that are with the Nashville District. If yes, provide title/description, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role. Please also clearly delineate the percentage of work you personally are currently conducting for the Nashville District. Please explain.
- Any previous employment by the USACE as a direct employee, notably if employment was with the Nashville District. If yes, provide title/description, dates employed, and place of employment (district, division, Headquarters, ERDC, etc.), and position/role.

² Includes any joint ventures in which a panel member's firm is involved and if the firm serves as a prime or as a subcontractor to a prime.

- Any previous employment by the USACE as a contractor (either as an individual or through your firm²) within the last 10 years, notably if those projects/contracts are with the Nashville District. If yes, provide title/description, dates employed, and place of employment (district, division, Headquarters, ERDC, etc.), and position/role.
- Previous experience conducting technical peer reviews. If yes, please highlight and discuss any technical reviews concerning dam safety and/or flood risk management and include the client/agency and duration of review (approximate dates).
- Pending, current, or future financial interests in USACE contracts/awards related to the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- A significant portion (i.e., greater than 50%) of personal or firm² revenues within the last 3 years came from USACE contracts.
- A significant portion (i.e., greater than 50%) of personal or firm² revenues within the last 3 years from contracts with FERC; Tennessee Department of Transportation; or Tennessee Wildlife Resources Agency.
- Any publicly documented statement (including, for example, advocating for or discouraging against) the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee project.
- Participation in relevant prior and/or current federal studies relevant to the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- Previous and/or current participation in prior non-federal studies relevant to the Supplemental MRER for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee.
- Is there any past, present, or future activity, relationship, or interest (financial or otherwise) that could make it appear that you would be unable to provide unbiased services on this project? If so, please describe.
- Future involvement of you, or your firm², on follow-on construction contracts like the RCC project (the tentatively selected plan) that would slant your review towards one alternative or another, based upon a relationship or financial interests with a potential bidder on the selected alternative work for this overall project.

In selecting the final members of the Panel, Battelle chose experts who best fit the expertise areas and had no COIs. One of the five final reviewers is affiliated with an academic institution, one is an independent consultant, and the other three are affiliated with consulting companies. Battelle established subcontracts with the panel members when they indicated their willingness to participate and confirmed the absence of COIs through a signed COI form. USACE was given the list of candidate panel members, but Battelle made the final selection of the Panel. Section 4 of this report provides names and biographical information on the panel members.

3.3 Conduct of the IEPR

Prior to beginning their review and within 1 day of their subcontracts being finalized, all members of the Panel attended a kick-off meeting via teleconference planned and facilitated by Battelle in order to review the IEPR process, the schedule, communication procedures, and other pertinent information for the Panel. Battelle planned and facilitated a second kick-off meeting in person on August 23, 2013, prior to the site visit, during which USACE presented project details to the Panel. Before the meetings, the IEPR Panel received an electronic version of the final

charge as well as the Center Hill Dam Supplemental MRER review documents and reference materials listed below. The documents and files in bold font were provided for review; the other documents were provided for reference or supplemental information only.

- **Center Hill Dam Supplemental MRER (192 pages)**
- **Appendix A – References (4 pages)**
- **Appendix B – PFMA Documentation 29 pages)**
- **Appendix C – Initiating Events (27 pages)**
- **Appendix D – System Response (6 pages)**
- **Appendix E – Consequence Documentation (16 pages)**
- **Appendix F – Risk Engine Results (27 pages)**
- **Appendix G – Pertinent Project Data Used in Risk Estimates (267 pages)**
- **Appendix H – Saddle Dam Stability Calculations (23 pages)**
- **Appendix I – Environmental Compliance (196 pages)**
- **Appendix J – Real Estate (17 pages)**
- **Appendix K – Cost Estimating (41 pages)**
- **Appendix L – Potential Failure Mode Illustrations (7 pages)**

Supplemental Documents

- Seepage Control Major Rehabilitation and Evaluation Report (2006 Report, 87 pages)

Reference Documents

- Office of Management and Budget's *Final Information Quality Bulletin for Peer Review* released December 16, 2004.

The following USACE regulations were followed in conducting the IEPR. The most recent ECs, ERs, Engineer Manuals (EMs), and Engineer Pamphlets (EPs) were used, which are available at: <http://140.194.76.129/publications/> or <http://www.hnd.usace.army.mil/techinfo/engpubs.htm>.

General

- EC 1105-2-410, Review of Decision Documents, 22 August 2008
- EC 1105-2-412, Assuring Quality of Planning Models, 31 March 2011
- EC 1165-2-209, Water Resources Policies and Authorities - Civil Works Review Policy, Change 1, 31 January 2012
- EC 1165-2-214, Water Resources Policies and Authorities - Civil Works Review, 15 December 2012
- EC 1165-2-210, Water Resources Policies and Authorities - Water Supply Storage and Risk Reduction Measures for Dams, 9 April 2010

- EP 1110-2-13, Dam Safety Preparedness, 28 June 1996
- ER 1110-1-12, Engineering and Design - Quality Management, 31 March 2011 (Change 2)
- ER 1110-2-1150, Engineering and Design - Engineering and Design for Civil Works Projects, 31 August 1999
- ER 1110-2-1155, Engineering and Design - Dam Safety Assurance Program, 12 September 1997
- ER 1110-2-1156, Engineering and Design - Safety of Dams - Policy and Procedures, 28 October 2011
- ER 1110-1-8159, Engineering and Design - DrChecks, 10 May 2001.
- National Academy of Sciences, “Policy and Procedures on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports,” May 2003 for General Scientific and Technical Studies and Assistance: General Scientific and Technical Studies and Assistance. Available at: <http://www.nationalacademies.org/coi/index.html>
- Water Resources Development Act of 2007, Sections 2034 & 2035, Pub. L. 110-114. Privacy Act, 5 U.S.C. § 522a as amended

Environmental/Planning

- ER 1105-2-100, Guidance for Conducting Civil Works Planning Studies. CECW-P, 28 December 1990
- Council on Environmental Quality. 1978. Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act. 40 CFR Parts 1500-1508. Washington, DC: U.S. Government Printing Office (November 29, 1978).
- ER 200-2-2, Environmental Quality, Procedures for Implementing NEPA. CECW-RE (now CECW-A), 4 March 1988

Engineering Geology

- EM 1110-1-1804, Engineering and Design - Geotechnical Investigations, 01 January 2001
- ER 1110-1-1807, Engineering and Design - Procedures for Drilling in Earth Embankments, 01 March 2006
- EM 1110-1-1802, Geophysical Exploration for Engineering and Environmental Investigations, 31 August 1995

Geotechnical Engineering

- EM 1110-2-1901, Engineering and Design - Seepage Analysis and Control for Dams, 30 April 1993
- EM 1110-2-1902, Engineering and Design - Slope Stability, 31 October 2003
- EM 1110-2-2300, Engineering and Design - General Design and Construction Considerations For Earth and Rock-Fill Dams, 30 July 2004

- EM 1110-2-1908, Engineering and Design - Instrumentation of Embankment Dams and Levees, 30 June 1995
- ER 1110-2-110, Engineering and Design - Instrumentation for Safety Evaluations of Civil Works Projects, 8 July 1985

Materials Engineering

- ER 1110-1-1901, Project Geotechnical and Concrete Materials Completion Report for Major USACE Project, 22 February 1999
- EM 1110-2-1906, Laboratory Soils Testing, 20 August 1986
- ER 1110-2-1911, Engineering and Design - Construction Control for Earth and Rock-Fill Dams, 30 September 1995
- EM 1110-2-2000, Engineering and Design - Standard Practice for Concrete for Civil Works Structures, 31 March 2001

Structural Engineering

- EM 1110-2-2002, Evaluation and Repair of Concrete Structures, 30 June 1995
- EM 1110-2-2100, Engineering and Design - Stability Analysis of Concrete Structures, 1 December 2005
- EM 1110-2-2102, Waterstops and Other Preformed Joint Materials for Civil Works Structures, 30 September 1995
- EM 1110-2-2104, Engineering and Design - Strength Design for Reinforced-Concrete Hydraulic Structures, 20 August 2003
- EM 1110-2-2400, Engineering and Design - Structural Design and Evaluation of Outlet Works, 02 June 2003
- EM 1110-2-4300, Instrumentation for Concrete Structures, 30 November 1987
- ER 1110-2-100, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures, 15 February 1995

Hydraulic Engineering

- EM 1110-2-1602, Engineering and Design - Hydraulic Design of Reservoir Outlet Works, 15 October 1980
- EM 1110-2-1603, Engineering and Design - Hydraulic Design of Spillways, 16 January 1990
- EM 1110-2-2902, Engineering and Design - Conduits, Culverts, and Pipes, 31 March 1998
- EM 1110-2-3600, Engineering and Design - Management of Water Control Systems, 30 November 1987
- ER 1110-8-2 (FR), Inflow Design Floods for Dams and Reservoirs, 1 March 1991
- ER 1110-2-240, Water Control Management, 8 October 1998
- ER 1130-2-530, Flood Control Operations and Maintenance Policies, 30 October 1996

- ER 1110-2-8156, Preparation of Water Control Manuals, 31 August 1995.

About halfway through the review of the Center Hill Dam Supplemental MRER review documents, a teleconference was held with USACE, the Panel, and Battelle so that USACE could answer any questions the Panel had concerning either the review documents or the project. Prior to this teleconference, Battelle submitted 15 panel member questions to USACE. USACE was able to provide responses to some of the questions during the teleconference; the remaining panel member questions that required additional coordination within USACE were addressed by USACE by September 5, 2013.

In addition, throughout the review period, USACE provided revised review documents and additional supporting documents based on questions posed by the panel members. These documents were provided to Battelle and then disseminated to the Panel. The documents (listed by file name) provided to the Panel were:

- Chapter 6 HH 26Jun2013.doc
- Revised Chapter 9 on 28 Aug 2013 IEPR.pdf
- Revised Chapter 10 on 28 Aug 2013 IEPR.pdf
- Revised Appendix F Supplement DAMRAE Output Summary Tables.pdf
- Revised Appendix F Supplement Input Echo Event tree Project Inputs.pdf
- Commo All Public Meetings – Center Hill and Wolf Creek.pdf
- Commo cenhill slides and notes from public meeting at carthage.pdf
- Appendix H email.pdf
- Hydraulic Report CEN (2010 CISP Analysis).pdf
- SRPs Existing and RCC Berm.xlsx
- RCC Design without Grout Curtain.docx

3.4 Site Visit

An in-person meeting to discuss the Center Hill Dam project was held at the USACE Center Hill Dam Resource Manager's Shop Facility in DeKalb County, east of Nashville, Tennessee, on August 23, 2013. All five panel members and one Battelle staff member attended this meeting and the subsequent site visit. The meeting was conducted in two parts. The first part involved a detailed briefing by USACE of the project history, issues, actions, and Supplemental MRER. Panel members asked several questions during the presentation, and open discussion occurred. At the conclusion of the presentation, USACE, Battelle staff, and the panel members convened for the second part of the meeting, a site visit. USACE led Battelle and the Panel on a tour of the Center Hill Dam site; the tour included the base of the saddle dam, the site of the proposed RCC berm, the fuse plug emergency spillway section on top of the saddle dam embankment, the unique construction apparatus for construction of the barrier wall at the main dam embankment, and the area downstream of the concrete main dam and powerhouse and main dam embankment. USACE, Battelle, and panel members stopped at these various points to observe key dam safety issues, including various geologic, hydrologic, and NEPA considerations.

Throughout the site visit, USACE staff pointed out specific project features to help the panel members better comprehend previous events, repairs, and issues associated with the existing project features and the intent of the project remediation. USACE staff then answered questions posed by the panel members. This tour provided an opportunity for the panel members to see the project area and project features and to ask clarifying questions of the USACE Project Delivery Team (PDT).

Battelle prepared and submitted a meeting summary, which was delivered to USACE on September 25, 2013. The summary provided documentation of the discussions held and panel questions asked, as well as highlights from the site visit.

Following the site visit, the USACE PDT provided the presentation slides. These documents were provided to Battelle and then disseminated to the Panel. The documents (listed by file name) provided to the Panel were:

- Cen iepr site visit 2013 08 23 kickoff geology and dam safety slides.pdf
- Cen iepr1 site visit 2013 08 23 kickoff overview slides.pdf

3.5 Review of Individual Comments

The Panel was instructed to address the charge questions/discussion points within a charge question response table provided by Battelle. At the end of the review period, the Panel produced individual comments in response to the charge questions/discussion points. Battelle reviewed the comments to identify overall recurring themes, areas of potential conflict, and other overall impressions. As a result of the review, Battelle summarized the individual comments into a preliminary list of 18 overall comments and discussion points. Each panel member's individual comments were shared with the full Panel in a merged individual comments table.

3.6 IEPR Panel Teleconference

Battelle facilitated a 3.5-hour teleconference with the Panel so that the panel members could exchange technical information. The main goal of the teleconference was to identify which issues should be carried forward as Final Panel Comments in the Final IEPR Report and decide which panel member would serve as the lead author for the development of each Final Panel Comment. This information exchange ensured that the Final IEPR Report would accurately represent the Panel's assessment of the project, including any conflicting opinions. The Panel engaged in a thorough discussion of the overall positive and negative comments, added any missing issues of high-level importance to the findings, and merged any related individual comments. In addition, Battelle confirmed each Final Panel Comment's level of significance to the Panel.

At the end of these discussions, the Panel identified 14 comments and discussion points that should be brought forward as Final Panel Comments.

3.7 Preparation of Final Panel Comments

Following the teleconference, Battelle prepared a summary memorandum for the Panel documenting each Final Panel Comment (organized by level of significance). The memorandum provided the following detailed guidance on the approach and format to be used to develop the Final Panel Comments for the Center Hill Dam Supplemental MRER:

- **Lead Responsibility:** For each Final Panel Comment, one Panel member was identified as the lead author responsible for coordinating the development of the Final Panel Comment and submitting it to Battelle. Battelle modified lead assignments at the direction of the Panel. To assist each lead in the development of the Final Panel Comments, Battelle distributed the merged individual comments table, a summary detailing each draft final comment statement, an example Final Panel Comment following the four-part structure described below, and templates for the preparation of each Final Panel Comment.
- **Directive to the Lead:** Each lead was encouraged to communicate directly with the other panel members as needed and to contribute to a particular Final Panel Comment. If a significant comment was identified that was not covered by one of the original Final Panel Comments, the appropriate lead was instructed to draft a new Final Panel Comment.
- **Format for Final Panel Comments:** Each Final Panel Comment was presented as part of a four-part structure:
 1. Comment Statement (succinct summary statement of concern)
 2. Basis for Comment (details regarding the concern)
 3. Significance (high, medium, low; see description below)
 4. Recommendation(s) for Resolution (see description below).
- **Criteria for Significance:** The following criteria were used to assign a significance level to each Final Panel Comment:
 1. **High:** Describes a fundamental problem with the project that could affect the recommendation, success, or justification of the project. Comments rated as high indicate that the Panel analyzed or assessed the methods, models, and/or analyses and determined that there is a “showstopper” issue.
 2. **Medium:** Affects the completeness of the report in describing the project, but will not affect the recommendation or justification of the project. Comments rated as medium indicate that the Panel does not have sufficient information to analyze or assess the methods, models, or analyses.
 3. **Low:** Affects the understanding or accuracy of the project as described in the report, but will not affect the recommendation or justification of the project. Comments rated as low indicate that the Panel identified information (tables, figures, equations, discussions) that was mislabeled or incorrect or data or report sections that were not clearly described or presented.
- **Guidance for Developing Recommendations:** The recommendation section was to include specific actions that USACE should consider to resolve the Final Panel Comment (e.g., suggestions on how and where to incorporate data into the analysis, how and where to address insufficiencies, areas where additional documentation is needed).

Battelle reviewed and edited the Final Panel Comments for clarity, consistency with the comment statement, and adherence to guidance on the Panel's overall charge, which included ensuring that there were no comments regarding either the appropriateness of the selected alternative or USACE policy. During the Final Panel Comment development process, the Panel determined that 2 of the Final Panel Comments could be either dropped or merged into other Final Panel Comments; therefore, the total Final Panel Comment count was reduced to 12. At the end of this process, 12 Final Panel Comments were prepared and assembled. There was no direct communication between the Panel and USACE during the preparation of the Final Panel Comments. The Final Panel Comments are presented in Appendix A of this report.

4. PANEL DESCRIPTION

An overview of the credentials of the final five members of the Panel and their qualifications in relation to the technical evaluation criteria is presented in Table 2. More detailed biographical information regarding each panel member and his or her area of technical expertise is presented in the text that follows the table.

Table 2. Center Hill Dam Supplemental MRER IEPR Panel: Technical Criteria and Areas of Expertise

Technical Criterion	Lambert	Shakoor	Voigt	Bastian	Crouch
Geotechnical Engineering					
Minimum 15 years of demonstrated experience in the specific field of dams engineering in evaluating, designing, and constructing large embankment dams (>100 feet high)	X				
Experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues	X				
Expert in seepage and piping issues in karst geology	X				
15 years or more experience in the general field of geotechnical engineering	X				
Experience in subsurface investigations; field and laboratory testing and the determination of in-situ material properties; soil compaction and earthwork construction; soil mechanics; seepage and piping; bearing capacity and settlement; design and construction of foundations on alluvial soils; and foundation inspection and assessment	X				
Experience with foundation grouting and other foundation treatment methods, including construction of foundation seepage barriers and the design, installation, and assessment of instrumentation	X				
Knowledge and experience in the forensic investigation of seepage, settlement, stability, and deformation problems associated with embankments constructed on alluvial soils.	X				
Familiarity with USACE dam safety assurance policy and guidance, including applicable risk assessment methodology	X				

Table 2. Center Hill Dam Supplemental MRER IEPR Panel: Technical Criteria and Areas of Expertise (Continued)

Technical Criterion	Lambert	Shakoor	Voigt	Bastian	Crouch
B.S. degree or higher in engineering	X				
Active participation in related professional societies	X				
Registered Professional Engineer	X				
Engineering Geologist					
15 years or more of demonstrated experience in the general field of engineering geology		X			
Extensive experience in major dam rehabilitation projects		X			
Experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues		X			
Proficient in assessing seepage and piping through and beneath dams constructed on or within various geologic environments including but not limited to alluvial soils, colluvium, and other geological formations		X			
Familiar with and knowledgeable of identification of geological hazards; field and laboratory testing and the determination of in-situ material properties; and foundation inspection and assessment		X			
Familiar with foundation grouting and other foundation treatment methods, including construction of foundation seepage barriers and design, installation, and assessment of instrumentation		X			
Familiarity with preparation of factual data and interpretative geology reports, including the preparation of Geotechnical Baseline Reports for USACE projects.		X			
Active participation in related professional societies		X			
Registered Professional Geologist		X			
Hydraulic and Hydrology (H&H) Engineering					
Minimum 10 or more years of experience in H&H engineering with an emphasis on the analysis and design of dams, including outlet works and spillways			X		
Experience performing dam breach and dam safety analyses			X		
Experience with large Civil Works flood risk management projects with USACE application of risk analysis for dam safety investigations			X		
Experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues			X		
Degree in H&H engineering or related field			X		
Active participation in related professional societies			X		
Registered Professional Engineer			X		

Table 2. Center Hill Dam Supplemental MRER IEPR Panel: Technical Criteria and Areas of Expertise (Continued)

Technical Criterion	Lambert	Shakoor	Voigt	Bastian	Crouch
Economics/Planning					
Minimum 10 or more years of experience directly related to water resource economic evaluation or review				X	
Direct experience working with USACE				X	
Familiar with the USACE plan formulation process, procedures, standards, guidance, and economic evaluation techniques				X	
Familiar with the USACE flood risk reduction analysis and economic benefit calculations				X	
Familiar with the use of standard USACE computer programs, including Hydrologic Engineering Center-Flood Impact Analysis (HEC-FIA)				X	
Demonstrated experience working with project teams to identify and evaluate measures and alternatives using appropriate planning methodologies to reduce life safety risk.				X	
Experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues				X	
B.S. degree or higher in economics				X ^a	
Environmental Planner / NEPA Impact Assessment					
Environmental planner / wetland ecologist / fisheries biologist / scientist with 10 or more years of experience					X
Experience directly related to water resource environmental evaluation or review, implementation of the NEPA compliance process, and Endangered Species Act requirements					X
Extensive demonstrated experience in the environmental assessment (EA) process with knowledge of the NEPA process, cultural surveys, biological assessments (BAs), endangered species, and working with inland lakes and with lake and river ecosystems					X
Experience evaluating and conducting NEPA impact assessments, including cumulative effects analyses, for complex multi-objective public works projects with competing tradeoffs.					X
Familiar with USACE calculation and application of environmental impacts and benefits					X
Familiar with determining the scope and appropriate methodologies for impact assessment and analyses					X
Experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues					X
M.S. degree or higher in related field					X
Active participation in related professional societies					X

^a Waiver statement presented as part of Task 2 deliverable and approved by USACE

Michael Lambert, P.E.

Role: Geotechnical engineering expertise

Affiliation: Shannon & Wilson, Inc.

Michael Lambert, P.E. is a geotechnical engineer with Shannon & Wilson, Inc., overseeing site investigations, developing geotechnical-related design and construction recommendations, developing and reviewing project plans and specifications, and monitoring compliance with project plans and specifications. He earned his M.Eng. in civil engineering from the University of Louisville in 1988, has more than 25 years of experience as a geotechnical engineer and project manager, and is a registered Professional Engineer in Missouri, Arkansas, Oregon, Tennessee, and California.

Mr. Lambert has demonstrated experience in evaluating, designing, and constructing large embankment dams (more than 100 feet high). He served as the Project Manager and Lead Geotechnical Engineer for the design of a dam raise for Lake Fort Smith Dam, Arkansas. This is a 200-foot earth and rock fill dam constructed as a raise to an existing 50-foot earth dam. He was the Project Manager and Lead Geotechnical Engineer for a project to add hydroelectric power to the existing USACE Jennings Randolph Dam, Maryland and served as the Senior Geotechnical Engineer for a review of a U.S. Bureau of Reclamation design to raise the existing Scoggins Dam, Washington by 20 to 40 feet. Mr. Lambert has experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues. As part of the review for the Scoggins Dam, an evaluation of risks associated with the proposed raise and possible failure modes was conducted.

Mr. Lambert has experience with seepage and piping issues in karst geology. He served as the Senior Geotechnical Engineer for several building projects constructed over or near karst features. A specific example is the Mormon Temple in St. Louis, which is located directly on top of a sinkhole, the remediation of which he designed. He also served as the Senior Geotechnical Engineer for two small dams constructed in areas of karst features. Extensive seepage and piping analyses were performed for these projects.

Mr. Lambert has experience with numerous building and infrastructure projects involving subsurface investigations. Examples include the Howard Bend Levee, Missouri; Jennings Randolph Dam; and Lake Fort Smith, all of which had extensive subsurface investigations with boring counts totaling well over 300. Mr. Lambert has experience with drilling and laboratory testing and many site visits for field observations during construction. Field testing included drilling, standard penetration test (SPTs), vane shear tests, density tests, proof rolling, pumping tests, slug testing, and falling weight deflectometer testing. Laboratory tests include Atterberg limits, moisture content, unconfined compression (soil, rock, concrete, and grout), triaxial compression, direct shear, consolidation, permeability, grain size, slake durability, resistivity, pH, and pin hole dispersion.

Mr. Lambert has worked on numerous commercial and infrastructure projects with earth and rock fills approaching 200 feet in height. These projects required the application of soil compaction testing using sand cone, drive tubes, nuclear densometer, and visual methods, all of which required an understanding of soil mechanics. Mr. Lambert has worked on several building

and infrastructure projects that required various bearing capacity and settlement calculations. Specific projects include several 10- to 15-story buildings in Clayton, Missouri; ancillary structures at the above-listed dam projects; and numerous small commercial projects across the Midwest bearing on shallow foundations, piles, or drilled shafts. Each of these projects included an evaluation of expected settlement. Additional projects that required complex or unusual settlement calculations include the Howard Bend Levee project (levee being constructed over an existing pipeline) and the Alder Creek Salmon Restoration Project, California (large fill area adjacent to existing levee and pipeline).

Mr. Lambert has experience with building and infrastructure projects constructed on alluvial soils. The foundation types include spread footings, mats, driven piles, drilled shafts, and auger-cast-in-place piles. The types of buildings being constructed include warehouses, parking garages, hotels, and casinos. Many of the building and infrastructure projects required foundation inspections that were performed or reviewed by him. These include driven piles, drilled shafts, auger-cast-in-place piles, spread footings, and mat foundations.

Mr. Lambert has experience with foundation grouting and other foundation treatment methods, including construction of foundation seepage barriers and the design, installation, and assessment of instrumentation. The Lake Fort Smith Dam project included a grout line to reduce seepage through the rock foundation. Mr. Lambert reviewed the installation of the grout line. The Lake Fort Smith Dam includes a significant instrumentation program that incorporates movement monuments, settlement rings, inclinometers, piezometers, and time-domain reflectometers (TDR). As part of his work for the Lewiston Levee project in Idaho, he reviewed the instrumentation data relative to observed seepage and levee performance. For the MnRoad Research project, Minnesota he served as the Project Manager and primary instrumentation engineer. The MnRoad Research project included the design, installation, and monitoring of several thousand instruments in 40 different test sections along 3 miles of interstate highway. A total of 24 different instrument types were placed throughout the sub-grade, base, and pavement layers to measure conditions and performance of the highway. The measurements consisted of temperature, moisture, frost penetration, horizontal and vertical deformation, static strain, dynamic strain, static stress, dynamic stress, rotation, acceleration, pore water pressure, water levels, and water flow. Specific instruments used on the project included TDRs, dynamic quarter and full bridge strain gauges, vibrating wire strain gauges and pressure cells, resistivity probes, tilt meters, and accelerometers.

Mr. Lambert has knowledge and experience in the forensic investigation of seepage, settlement, stability, and deformation problems associated with embankments constructed on alluvial soils. He has reviewed numerous levee and dam projects across the United States. Many of these structures had one or more of these issues, and all were constructed on alluvial soils. Specific projects include Lake Fort Smith, Lewiston Levee, Mississippi River levees, and Missouri River levees.

Mr. Lambert has familiarity with USACE dam safety assurance policy and guidance, including applicable risk assessment methodology. He is currently working on a SAR for the USACE St. Louis District. As design engineer on over a dozen USACE projects, he has a thorough understanding of USACE design methodologies associated with water-retaining structures and is capable of addressing USACE SAR aspects of projects. He has published technical papers in his

field of expertise and remains involved with professional organizations, including the American Society of Civil Engineers (ASCE), Society of American Military Engineers (SAME), and the Association of State Dam Officials.

Abdul Shakoor, P.G., Ph.D.

Role: Engineering geology expertise

Affiliation: Kent State University/Independent Consultant

Abdul Shakoor, Ph.D., P.G., earned his Ph.D. in engineering geology in 1982 from Purdue University. He is currently a professor of engineering geology and has 45 years of experience in teaching, researching, and practicing engineering geology. His research spans the inter-related fields of engineering geology and geotechnical engineering; his consulting work has focused on dam engineering, slope stability, mine subsidence, damage caused by blasting operations, and engineering characterization and behavior of soils and rocks. He is a certified professional geologist with the American Institute of Professional Geologists and a registered Professional Geologist in Pennsylvania.

Dr. Shakoor has participated in previous dam safety peer reviews focused on major dam rehabilitation studies, including Bluestone, West Virginia; Dover, Ohio; Bolivar, Ohio; and Lake Isabella, California, dam projects. Two of his graduate students have worked on dam projects; one focused on seepage and piping problems associated with epikarst material present at the Clearwater Dam, Missouri, and another for the Wolk Creek Dam, Kentucky. As part of his oversight, Dr. Shakoor became familiar with the rehabilitation being carried out on these two dams.

Dr. Shakoor regularly teaches about seepage and piping problems under the topic of stability analysis for dams, including computing seepage quantities using flow nets, determining uplift pressure using flow nets and piezometric data, and evaluating piping potential through and beneath embankment dams. He has also been involved in assessing seepage and piping problems and has a thorough understanding of subsurface flow as well as piping and seepage failure mode analysis at several dams spanning several decades. These include Mangla Dam, Pakistan; Chagrin River Dam, Ohio; Clearwater Dam, Missouri; Wolf Creek Dam, Kentucky; and Bolivar Dam, Ohio. The Mangla Dam was a 250-foot high, 1-mile long zoned embankment dam built on an alluvial foundation. Serving as a previous peer reviewer for the Bolivar and Lake Isabella dam projects provided Dr. Shakoor significant experience with seepage and piping problems associated with alluvial foundations. The Clearwater Dam and Wolf Creek Dam projects exposed him to seepage and piping problems associated with karst terrain.

Dr. Shakoor has experience in failure mode analysis and risk assessment of large dams. He has served on two international panels of consultants for two nearly 800-foot high RCC dams to be built on the Indus River in Pakistan. Both of these projects involved an evaluation of the potential modes of failure, risk assessment, and safety issues. He provided oversight to a graduate student who investigated the failure of the Upper Ivex Dam on Chagrin River, Ohio, a 90-foot-high combination structure consisting of a masonry arch and a long, homogeneous, embankment dike. The main failure mode and safety issues investigated were the seepage and piping along the contact between the two types of structures. As part of another project,

Dr. Shakoor provided oversight to a graduate student who investigated the 1911 sliding failure of the Austin Dam, Pennsylvania. The results of this research were published in *Environmental & Engineering Geoscience*. Additionally, his experience serving as an IEPR member for the Bluestone, Dover, Bolivar, and Lake Isabella Dam projects helped Dr. Shakoor gain extensive experience of failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues.

Dr. Shakoor has more than 30 years of experience examining landslides and related geomorphic features; has published nearly 30 landslide-related papers; and is currently involved in developing a computer model for landslide identification using light detection and ranging (LiDAR) data. He has expertise in evaluating geologic hazards relating to slope instability, mine subsidence, and expansive soils, and he has served as an expert witness in court cases involving slope movements. Dr. Shakoor teaches exploration techniques in detail, including field observations, measurements, geophysical methods, and mapping as well as subsurface exploration. His slope stability studies have used instrumentation data from slope inclinometers, TDR cables, and vibrating wire piezometers. He has vast experience with field testing such as SPT, Schmidt hammer, point load tester, pocket penetrometer, Torvane, and slug tests.

Dr. Shakoor has been teaching and researching geologic hazards (e.g., slope movements, volume changes in soil and rock, mine subsidence, etc.) throughout his professional career and has been involved in consulting work on slope stability-related hazards. He and his students have developed a rockfall hazard rating system and a cut-slope design manual for the Ohio Department of Transportation. Dr. Shakoor is very familiar with all types of field and laboratory testing of soil and rock materials. His soil mechanics and advanced engineering geology courses have regular labs for engineering property testing of soils and rocks, and most of his research projects involve both laboratory and in-situ testing. Dr. Shakoor teaches a course on foundation engineering. As a part of this course, he has made trips with his students to multiple sites where both shallow and deep foundations were under construction.

Dr. Shakoor is very familiar with foundation grouting and seepage barriers in general. His experience in this area is based on his teaching and research as well as his service as an IEPR panel member for several dam projects. He teaches foundation grouting in his introductory and advanced engineering geology courses. His research at the Clearwater Dam exposed him to state-of-the-art grouting operations and the proposed seepage barrier. As a member of other IEPR teams, he has been involved in reviewing grouting operations for both foundations and anchor installation. In this capacity, he also reviewed the seepage barrier plans for the Bolivar and Lake Isabella Dams. He has significant experience in the design and assessment of instrumentation relating to dams and slopes, including monitoring, data collection, and data interpretation of such instrumentation as settlement pins, slope inclinometers, piezometers, crack propagation gauges, and uplift pressure gauges in dam galleries.

As a researcher in the field of engineering geology, Dr. Shakoor is familiar with the preparation of factual data and interpretative geology reports, including the preparation of geotechnical baseline reports for USACE projects. As part of the IEPR for Lake Isabella Dam, he reviewed the baseline report for that project.

Dr. Shakoor is an active member of several professional societies, including the Geological Society of America, Association of Environmental & Engineering Geologists, ASCE, and International Society for Rock Mechanics. He is also the editor of *Environmental & Engineering Geoscience* and is a member of the Editorial Board of *Engineering Geology*.

Richard Voigt, P.E.

Role: Hydraulic and Hydrology engineering expertise

Affiliation: Voigt Consultants, LLC

Richard Voigt, P.E., is the President of Voigt Consultants LLC in South St. Paul, Minnesota, and a registered Professional Engineer in Minnesota and Wisconsin. He earned his M.S. in civil engineering from the University of Minnesota in 1985 and has nearly 30 years of experience in the fields of dam and water resources engineering, specializing in complex hydraulic analyses and modeling. Much of his project experience is focused in the areas of hydropower, dams and spillways, numerical and physical hydraulic modeling, and hydrology.

Mr. Voigt's experience includes using one-, two- and three-dimensional models to evaluate flow patterns in rivers and near dams, spillways, and inlet and outlet structures. Prior to becoming a consultant in 1999, Mr. Voigt worked for 17 years at St. Anthony Falls Laboratory, University of Minnesota, spending his last 7 years as Associate Director of Applied Research. During his time at the laboratory, he was an active participant on several dam and spillway projects. He served as the project engineer for the design-development-testing of all aspects of the Jim Falls Hydroelectric Facility, Wisconsin including modifications to the powerhouse tailrace to improve plant efficiency and the design of an asymmetrical stilling basin to fit site constraints. He was the project manager and senior engineer in charge of the design and testing of a high-velocity outlet structure for Blue River Dam, Oregon and the testing of the upper intake and outlet structure and the penstock system for the Rocky Mountain Pumped Storage Facility under both pump and turbine modes. He also was the project manager and senior engineer for the Bee Tree Dam Spillway Capacity Expansion Project, North Carolina and the evaluation of air ramp alternatives for the 15 de Septiembre Spillway, El Salvador.

As a consultant, Mr. Voigt was the project manager and principal engineer for the preliminary design of fuse plug and flash board spillway alternatives for Kings Dam, Wisconsin. He also analyzed the cause of repeated wave-induced trip gate failures at Byllesby Dam, Minnesota. He was a design consultant for the hydraulic design of reservoir outlets, spillways, and energy dissipaters for the C-43 West storage reservoir in Florida. The hydraulic design of the C-43 West project outlets included sizing the gated control sections and determining the type of service and emergency gates. He also consulted on the design of the appropriate conduit profile and venting requirements and the susceptibility for vortex formation at the conduit inlet.

Mr. Voigt has worked on a number of dam breach and related dam safety analyses. He has conducted assessment modeling of breach formation and propagation in an area of vegetated natural soils that function as an emergency spillway at the Cheboygan Dam in Michigan. The upstream end of the natural soil is protected by a sheet pile wall of unknown depth, and previous dam break and BREACH models indicated that failure of the area of natural soil was unlikely. FERC requested that additional analyses be performed. Mr. Voigt's review indicated that if the

flood hydrograph was of long enough duration and sufficient magnitude to cause removal of the vegetative cover, a range of discharges could create a combination of erosive discharge over the natural soil in conjunction with tailwater elevations that could result in the formation of a headcut on the downstream edge of the natural soil adjacent to the riverbank. Headcut advancement rates were determined for different conditions to estimate the time necessary for the headcut to propagate through the natural soils to the sheet pile wall, creating conditions suitable for potential failure.

Mr. Voigt also conducted a dam breach analysis to evaluate the water surface elevations created by the failure of Sylvan Dam, Minnesota. The analysis was performed using an unsteady Hydrologic Engineering Center-River Analysis System (HEC-RAS) model calibrated to match the model stage-discharge relationship to the field data. Evaluations were completed for various breach scenarios, and the impacts of water level rise along the downstream river reach were analyzed to estimate the inflow design flood (IDF).

Mr. Voigt conducted an evaluation of spillway alternatives to increase the capacity of Pillager Dam to meet the IDF. The evaluation reviewed the potential options for meeting the capacity and the estimated cost for each alternative. The analysis also evaluated the impact that incremental increases in spillway capacity would have on the IDF determination.

Mr. Voigt has performed dam breach analyses using HEC-1 and HEC-2 to determine preliminary Federal Emergency Management Agency (FEMA) Hazard Classification of Gordon and Clam Falls Dams in northwestern Wisconsin. Follow-on work to these dams included converting models to Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) and HEC-RAS and expanding the models to assess the impacts of different dam break scenarios and the possible extent that flood waves would propagate downstream. For another project, Mr. Voigt developed a dam break model using HEC-RAS for the St. Cloud Dam, Minnesota to assess the potential breaching of a low area of the right embankment upstream from the dam.

Mr. Voigt has developed gate rating curves for Winter, Wisconsin; Four Mile, Michigan; Norway Point, Michigan; Clam River, Wisconsin; Rapidan, Minnesota and other North American hydropower projects. He was the project engineer for a subconsultant assisting with the H&H analyses of the effectiveness of depressional storage within the Devils Lake watershed, North Dakota. The evaluation used Geographic Information System (GIS) data to delineate and classify over 100,000 depressions based upon U.S. Bureau of Reclamation photos, National Wetlands Inventory maps, and soils survey maps. The entire 2,600-square-mile watershed was modeled using HEC-HMS and other routines specifically designed to address the unique characteristics of the prairie pothole region.

Mr. Voigt evaluated the 100-year and 500-year floodplain status as part of the Environmental Assessment (EA) Worksheet for the \$165 million Upper Landing Urban Village on the Mississippi River at St. Paul, Minnesota. He submitted to and received approval from FEMA for the initial Conditional Letter of Map Revision based on fill for the entire Upper Landing Urban Village as well as Letters of Map Revision based on fill for each of the blocks as they were developed. Tasks included (1) working with the City of St. Paul, the Minnesota Department of Natural Resources (MnDNR), and FEMA staff to modify sections of the city's flood ordinance

to comply with MnDNR regulations, (2) analyzing the flood susceptibility of each block, and (3) designing building groundwater seepage control and underground building drainage systems.

As the hydraulic engineering consultant for the Lower St. Anthony Falls project, Minnesota, Mr. Voigt developed two-dimensional models using RMA-2 for reaches both upstream and downstream of the dam to review potential flow pattern changes near the lock and dam area related to the proposed installation of a hydropower plant in the auxiliary lock chamber. Mr. Voigt was actively involved in the review of any changes the development could have to the performance, maintenance, and safety of the lock and dam and conducted numerous evaluations of different items of concern. He participated in the potential failure mode (PFM) analysis for the project. He recently served as the facilitator for a supplemental PFM analysis of the design of repair alternatives to the Brainerd Dam, Minnesota. He also attended the first phase of risk-informed decision making training conducted by FERC in December 2012; he is scheduled to attend level-two training this fall.

Mr. Voigt is a member of the International Association of Hydraulic Research and the SAME. He also serves on the Board of Directors of the Midwest Hydro Users Group.

David Bastian, P.E.

Role: Economics/planning expertise

Affiliation: Independent Consultant

David Bastian, P.E. is an independent consultant and engineer for David Bastian Consulting in Annapolis, Maryland, specializing in USACE compliance and policy review, plan formulation and incremental cost analysis, flood risk reduction, and hydraulic and river engineering. He earned his B.S. in civil engineering from the Georgia Institute of Technology and a M.S. in River Engineering from Delft University, Holland. He is a registered Professional Engineer in Mississippi.

Mr. Bastian has over 35 years of experience with USACE and 10 years as contractor/consultant on USACE projects, with 30 years of demonstrated experience in public works planning. He has worked with project teams to identify and evaluate measures and alternatives using appropriate planning methodologies to reduce life safety risk. Specifically, as a Headquarters reviewer, he evaluated dam safety rehabilitation studies that centered on loss of life; in that capacity, he reviewed failure mode analysis and risk assessment of a number of dams and floodwall and levee systems.

Mr. Bastian's experience directly related to water resources economic evaluation and review includes the review of USACE water resources feasibility reports for technical and economic evaluation for 20 years. In addition, he has extensive experience reviewing the analyses used to evaluate measures and alternatives and is able to determine whether they are sufficiently comprehensive and complete to result in approval of recommended alternatives. He provided technical and policy compliance experience to all aspects of the Corpus Christi channel deepening project report such that the feasibility report met Headquarters requirements for project authorization. Mr. Bastian's previous employment at USACE included positions as Deputy Chief of Staff for Support, Office Chief of Engineers; Assistant Director of Civil Works,

Office Chief of Engineers; technical and policy compliance review expert, Washington Level Review Center; and navigation research, USACE Institute for Water Resources (IWR). He has managed interdisciplinary reviews of over 70 feasibility reports.

Due to his substantial experience as a USACE Headquarters feasibility study/environmental impact statement (EIS) reviewer, Mr. Bastian is knowledgeable in water resource environmental evaluation and review. He has prepared feasibility reports and provided independent technical review of flood damage reduction, ecosystem restoration, navigation, major rehabilitation, post-authorization, and dam safety assurance for Alaska, Galveston, Huntington, Jacksonville, Kansas City, Little Rock, Mobile, New Orleans, Tulsa, Vicksburg, and Norfolk Districts. His experience includes studies such as the New Orleans Hurricane Storm Damage Risk Reduction System study and associated series of interim environmental reports (2008 to 2010); Louisiana Coastal Area and Louisiana Coastal Protection and Restoration studies (2006 to 2008); the Texas City Container Terminal (2005); and the Spavinaw Creek Basin, Oklahoma (2006 to 2007).

Having worked in the USACE planning function for over 25 years, Mr. Bastian is proficient in the USACE plan formulation process, procedures, standards, guidance, and economic evaluation techniques and in the application of the USACE six-step process. He is also an expert on USACE policy, including ER 1105-2-100. In the course of his career, he has participated in the creation of and collaborated on over 100 USACE reports evaluating and comparing alternative plans.

Mr. Bastian is also familiar with USACE's dam safety assurance guidance and has reviewed project rehabilitation and dam safety studies for policy compliance for USACE Headquarters. He has evaluated and conducted National Economic Development analysis procedures, particularly as they relate to navigation, and hurricane and coastal storm damage risk reduction. He authored the deep-draft and inland navigation sections of the IWR Planning Workshop manual; participated in the IEPR of the Delaware River Deepening Feasibility Study (2003 to 2004); and contributed to the Port Everglades channel relocation and enlargement (2012) economic evaluation. He has been involved with programs with high public and interagency interests such as the post-Katrina Hurricane Storm Damage Risk Reduction System and is experienced with the USACE calculation and application of environmental impacts and benefits, determining the scope and appropriate methodologies for impact assessment and analyses for a variety of projects, and potential project impacts to nearby sensitive habitats.

Mr. Bastian is familiar with the USACE flood risk and hurricane/coastal damage risk reduction analysis and economic benefit calculations, including the use of standard USACE computer programs such as Hydrologic Engineering Center-Flood Impact Analysis (HEC-FIA). He has been called on to review HEC-FIA and other model applications and their outputs for several flood risk reduction and dam safety studies for technical economic justification. He has 10 years of experience identifying and evaluating impacts to environmental resources from structural flood risk management and hurricane and coastal storm damage risk reduction projects. His experience in the Gulf of Mexico is reflected in his 5 years of involvement with the review of decision documents involving EIS and NEPA requirements, as well as levee construction designs for New Orleans, Louisiana, post-Katrina projects.

Mr. Bastian's participation in professional societies includes the ASCE, the American Association of Port Authorities, the Permanent International Association of Navigation Congresses, and the Western Dredging Association.

Kay Crouch

Role: Environmental planning/NEPA Impact Assessment expertise

Affiliation: Crouch Environmental Services, Inc.

Kay Crouch is the President of Crouch Environmental Services, Inc., a company specializing in NEPA analysis, environmental site assessment, wetland permitting, and wetlands mitigation for projects with high public and interagency interests. She earned her M.S. in biology/ecology in 1978 from Steven F. Austin State University and has received additional academic training in the NEPA process from the Duke University Nichols School of Environmental and Earth Sciences (2004 to 2006). Ms. Crouch has over 35 years of nationwide experience conducting water resources projects, environmental site assessments, and preparing NEPA documentation for complex multi-objective public works projects with competing tradeoffs. She has performed numerous environmental evaluations in support of FERC filings and NEPA documentation. She is an expert at cumulative effects analysis and documentation, along with direct, indirect, and secondary effects.

For the first 10 years of her consulting career, Ms. Crouch worked predominantly in Louisiana performing NEPA analyses for oil and gas pipelines crossing the Louisiana Coastal Zone. Ms. Crouch is familiar with USACE calculations and application of environmental impacts and benefits. She routinely performs cumulative effects analyses on high-visibility public works projects as part of her extensive NEPA practice.

Ms. Crouch has extensive experience directly related to water resource environmental evaluation or review and has completed numerous NEPA projects for USACE. Specific NEPA projects she has worked on are the EIS for the Bayport Container Terminal, Texas and public involvement for the Sabine Neches Waterway and Clear Creek Flood Damage Reduction Project, Texas. Recently, Ms. Crouch planned, organized, and executed a public outreach plan for the Addicks and Barker Dam Safety Program (Houston, Texas). This effort was declared a "Best Practice" by USACE, for which Ms. Crouch and her staff received a written commendation from the Commander of the Galveston District. Other NEPA projects have consisted of flood damage reduction projects, dams, ports, parks, offshore activities, linear transportation corridors, and power plants and other types of projects involving federal funding.

Ms. Crouch has demonstrated experience with cultural surveys. Almost every project she works on requires an investigation and evaluation of cultural resource issues. She is intimately familiar with the record search step as well as field survey techniques for cultural resources. Her supervisory experience relates to USACE Section 404 permits and NEPA documentation. She also has Section 106 experience for the analysis of historical issues.

Ms. Crouch has demonstrated knowledge conducting biological assessments (BAs), including wetlands delineation, compilation of BAs for Section 404 permitting, mitigation planning and

execution, and NEPA documentation. Her experience spans numerous types of habitats in locations nationwide. Ms. Crouch is familiar with USACE calculation and application of environmental impacts and benefits. She is well-versed in various modeling types and in performing incremental cost analysis for mitigation evaluation for dam repair and restoration.

Ms. Crouch has 35 years of experience conducting endangered species presence and absence surveys, as well as long-term monitoring for listed species. She has completed numerous projects that involve compliance with the Endangered Species Act. For almost every project she is involved in, she is called on to evaluate the presence or absence of listed species. These include NEPA documentation as well as USACE Section 404 permit applications requiring field investigations for listed species in numerous states; she also has completed the Section 7 consultation process for several species.

Ms. Crouch has extensive experience working on lakes, inland lakes and riverine systems. During undergraduate school, while working on a National Science Foundation grant, she studied two Texas lakes. Her aquatic ecology work continued into her graduate work. As a wetlands specialist, she performs most of her work in waters of the United States, including both inland and coastal waters. She has worked on almost every major lake and inland waterway in the southeast region of Texas. This work has been primarily related to waters of the U.S. and wetlands, water quality sampling and analysis, BAs, listed species assessments, flood damage reduction studies, and NEPA analyses and documentation.

Ms. Crouch is familiar with determining the scope and appropriate methodologies for impact assessment and analyses. She evaluates the scope of impacts and utilizes appropriate methods for determining and mitigating impacts. Her IEPR review experience has also required much study and analysis of impact assessment and mitigation.

Ms. Crouch has experience in failure mode analysis and risk assessment of large complex systems with emphasis on dam safety issues. Her most recent experience involves the Addicks and Barker Dams and Reservoirs system in Harris County, Texas. This system keeps downtown Houston (with 4 million residents) from flooding. Recently, she completed an EA, in cooperation with the Galveston District, to repair and rebuild these dams, which were constructed in 1939. Along with that effort, she led a public education effort that resulted in 11 different public meetings, congressional briefings, and stakeholder meetings for both upstream and downstream residents.

Ms. Crouch has served as an environmental expert in previous IEPRs of USACE projects. She is a member of the Society of Wetland Scientists and founder and president of fundmyresearch.org. She is the vice-chair of HeartGift Houston.

5. SUMMARY OF FINAL PANEL COMMENTS

The panel members agreed among themselves on their “assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used” (USACE, 2012a; p. D-4) in the Center Hill Dam Supplemental MRER review documents. Table 3 lists the Final Panel Comment statements by level of significance. The full text of the

Final Panel Comments is presented in Appendix A of this report. The following summarizes the Panel's findings.

Based on the Panel's review, the report is well constructed to support a plan of action that would allow the Center Hill Dam to be reclassified from USACE's DSAC I rating to a DSAC IV. The documents demonstrate that the project has had fundamental problems due to the original construction and that USACE has taken steps to address the problems in a timely and effective manner by developing solutions that are likely to be generally effective at minimum cost. The Panel agreed that USACE used appropriate methods and models in its analysis and provided adequate detail in describing the processes followed throughout the project. While the Panel deemed the report comprehensive with robust documentation in many areas, it identified areas of inconsistencies attributed to recent updates to the report and a few areas where additional clarification is warranted. The Panel is also concerned that given the numerous updates supplied during the review, the changes made during the review may not be consistently applied throughout the document.

Engineering – USACE has done a very good job of identifying and describing the root cause of all problems at Center Hill Dam (i.e., the presence of karst). The review documents use water pressure test results, boring logs, construction photos, dye test results, breakouts, connections, and lack of refusal during grouting operations, and locations of water seeps, springs, and leaks to better understand the karst behavior at the project site. The Panel also found Appendix G to contain a great deal of crucial information. Panel members found it especially helpful that USACE used all previous records and data to understand the geology, cost features, grouting, and interactions. The major issue noted by the Panel concerns the performance of the erodible fuse plug (i.e., whether it will fail as designed), and the implications if it does not fail within 30 minutes or sufficiently fast enough to prevent other issues from arising. The consequences of the plug not failing within the designed 30 minutes or sufficiently fast enough to prevent other issues from arising is not addressed in the document provided. Premature failure of the fuse plug is only partially addressed in the document provided. These issues can be readily addressed by describing the fuse plug failure process over time, providing the results of the sensitivity analysis, and further exploring the impacts of dismissed potential failure modes (PFMs) in the Supplemental MRER.

The Panel is also concerned about the assumed increase in frictional strength along monolith contacts and other internal surfaces due to concrete expansion associated with alkali-aggregate reaction (AAR). The Panel is concerned that the assumed increase in frictional strength, not supported by any quantitative data, may not exist and therefore reduce the overall safety of the project and may have resulted in the elimination of a PFM or require additional mitigation measures at the main dam. The Panel suggests that further clarification about the assumptions regarding AAR and its applicability to PFMs 19A and 18B be provided to help address this concern. In addition, PFMs 6, 8, and 10 may have been dismissed prematurely, thereby affecting which remediation alternative is selected, and could therefore affect project benefits. This issue could be easily addressed by reviewing these PFMs to determine if one or more should be more fully developed.

Economics – The Panel believes that the summary of the event tree analysis for the significant failure modes and the alternatives that USACE has provided in the Center Hill Dam

Supplemental MRER strengthens the understanding of the project. Furthermore, Appendix K provides a thorough presentation of costs regarding this dam safety project. However, the Panel has some concern about the left rim grout curtain and the right rim seepage. Since cost is neither constant nor predictable, the Panel believes that USACE should further investigate the costs for these two abutments. The Panel also notes that the definition of PFM 16 is inconsistent between the Supplemental MRER main report and Appendix B.

The accuracy of the reported remaining benefit-cost ratio could not be verified because it is unclear whether assumptions associated with remediation of the saddle dam or the barrier wall were used to generate the remaining benefits. The Supplemental MRER would benefit from a list of the assumptions used. It is also unclear whether the economic analysis has taken into consideration the annualized benefits of power and water supplied by the Center Hill Dam in relation to the annualized cost of the most likely alternative. Including information for the basis for using payment agreements instead of the costs incurred by the consumer for alternative water and power supply would provide clarification to the Supplemental MRER economic analysis.

Environmental – The Panel recognizes that the Supplemental MRER, while concisely written, is thorough and comprehensive; however, as recognized in the document, the environmental documentation is not quite complete. The potential effects of climate change on the tentatively selected plan are not considered, including potential effects on the Probable Maximum Flood (PMF) and reservoir elevation. This issue can be addressed by (1) describing the potential effects of climate change and how these potential effects were considered during the plan formulation process, and (2) revising the probability of failure if the reservoir stage versus probability function changes as a result of new calculations considering climate change parameters. Resolution on treatment of the contaminated area where used timbers were formerly stored needs to be addressed.

Several topics customarily discussed in NEPA documentation were not included in the environmental summary of the Center Hill Dam Supplemental MRER or in the environmental assessment (EA). This can be addressed by including a brief discussion of construction effects and a mention of negative findings for potential federally or state-listed karst species. In other instances, some topics (sinkhole repairs, left rim stabilization, dam safety clearing, and weir repairs) either have incomplete descriptions or are still referenced, even though they are no longer part of the tentatively selected plan.

Plan Formulation – The Panel found that the plan formulation process is easy to follow and that the assumptions, methodologies, and results provide a well-reasoned and systematic basis for selecting the tentatively selected plan. It is apparent that a great deal of work has been expended regarding agency coordination and public communication; however, a summary of this outreach is not included and may be viewed as having been overlooked. In addition, outlining the agency and public communications that have occurred to date would strengthen the Supplemental MRER.

Table 3. Overview of 12 Final Panel Comments Identified by the Center Hill Dam Supplemental MRER IEPR Panel

No.	Final Panel Comment
Significance – High	
1	Uncertainty exists regarding whether the Center Hill Dam's erodible fuse plug will fail within 30 minutes, as designed.
2	The assumption that the alkali-aggregate reaction (AAR) increases normal stress on monolith contacts or other surfaces within the monoliths (and therefore adds to surface frictional resistance) is not supported by quantitative data.
Significance – Medium	
3	Several potential failure modes (PFMs) may have been dismissed prematurely, thereby potentially affecting project benefits.
4	The system response probabilities for Potential Failure Modes (PFMs) 7A, 7B, 7C, and 7D and their relationship to PFM 7 are not clearly presented in the documentation, and the choice of PFM 7C over 7D is not fully supported.
5	Apparent discrepancies in different sets of the dam breach modeling information and inconsistencies in the level of detail between different analyses made it difficult to assess the dam breach model.
6	The project documentation does not account for the possibility that additional seeps could develop in the groin area and impact the main dam embankment.
7	The effects of climate change on the Probable Maximum Flood (PMF) and the magnitude of the reservoir elevation have not been evaluated.
8	The assumption that upper and lower leaks in the right rim are primarily due to solution channels along the bedding planes is not valid.
Significance – Low	
9	Several topics customarily addressed to comply with the National Environmental Policy Act (NEPA) either are not discussed in the project documentation or received minimal discussion, and some sections of the environmental assessment (EA) refer to measures that are no longer part of the tentatively selected plan.
10	It is unclear whether the economic analysis has taken into consideration the annualized benefits of power and water supply from the Center Hill Dam in relation to the annualized cost of the most likely alternative.
11	It is not clear what approach will be used to cap or restore an area of hazardous materials that leached from treated timber formerly stored on the site.
12	A detailed correlation between discontinuity orientations and known seepage pathways (karst features) has not been established.

6. REFERENCES

Brekke, L.D., Kiang, J.E., Olsen, J.R., Pulwarty, R.S., Raff, D.A., Turnipseed, D.P., Webb, R.S., and White, K.D. (2009). Climate change and water resources management—A federal perspective: U.S. Geological Survey Circular 1331, 65 p. Available online at <http://pubs.usgs.gov/circ/1331/>.

OMB (2004). Final Information Quality Bulletin for Peer Review. Executive Office of the President, Office of Management and Budget, Washington, D.C. Memorandum M-05-03. December 16.

The National Academies (2003). Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports. The National Academies (National Academy of Science, National Academy of Engineering, Institute of Medicine, National Research Council). May 12.

Rocscience (2013). Dips - Graphical and Statistical Analysis of Orientation Data, version 6.0. Rocscience Inc. - Software Tools for Soil and Rock, University of Toronto, Canada.

USACE (2000). Planning Guidance Notebook. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Regulation (ER) No. 1105-2-100. April 22.

USACE (2012a). Water Resources Policies and Authorities: Civil Works Review. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Circular (EC) No. 1165-2-214. December 15.

USACE (2012b). Climate Change Adaptation Plan and Report. U.S. Army Corps of Engineers. June 2012.

USACE (2013). Responses to Climate Change. U.S. Army Corps of Engineers website dated January 14, 2013. Available at www.corpsclimate.us/. Accessed September 13, 2013.

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APPENDIX A

Final Panel Comments

on the

Center Hill Dam Supplemental MRER

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Final Panel Comment 1

Uncertainty exists regarding whether the Center Hill Dam's erodible fuse plug will fail within 30 minutes, as designed.

Basis for Comment

The Panel is concerned about the underlying assumption that the fuse plug will completely fail within 30 minutes of overtopping. Panel members believe that complete failure in such a short time period is not realistic given the tightly interlocked nature of the riprap on the crest and downstream face and the need to erode the 8- or 9-foot-thick clay core. In addition, because some of the downstream sand and gravel layer was replaced with crushed angular material used during construction, the rate of initial unraveling of the material may be impeded.

Premature failure of the fuse plug has been largely ruled out due to the integrity of its design and construction; however, these same features could prevent the fuse plug's rapid and timely failure. The documentation provided does not clearly state the exact level at which the breach initiation is assumed to occur. At 30 minutes following theoretical initiation and without any fuse plug failure, the water level will have risen approximately 1 to 1.5 additional feet from the water level at the assumed point of initiation. The Panel is not sure that the flow will have sufficient energy to trigger rapid erosion of the fuse plug, especially the core.

The consequences of the fuse plug not eroding within 30 minutes during the passage of the Probable Maximum Flood (PMF) have not been adequately identified and described. If the existing fuse plug does not function as designed, the residual risk may exceed existing guidelines. No analysis or consideration of this risk is noted in the review documents.

It was indicated during the site visit that 2 hours were available during which failure of the fuse plug could occur without endangering the project. This assertion was further clarified in response to mid-review conference call Question 14:

"As part of the [roller compacted concrete (RCC)] Berm placement and weir size design, we completed [Hydrologic Engineering Center-River Analysis System (HEC-RAS)] modeling to investigate backwater effects on the fuse plug. We want to make sure the RCC Berm does not inhibit normal operation of the fuse plug. Based on a sensitivity analysis, if it takes 2 hours for the fuse plug to fail (as opposed to the 30 minutes it is designed to completely erode within), the lake level will not overtop the main embankment dam but will encroach into the 3.6-feet of freeboard allotted for wind and wave run-up. This encroachment would occur for as much as 6 hours. In [Agency Technical Review (ATR)] discussions, it was determined that this condition could easily be addressed by constructing a curb of a few inches that would increase the freeboard of the main dam."

Significance – High

The ability of the fuse plug to function as designed affects the overall safety of the project and may affect the selection of the proposed alternative.

Recommendations for Resolution

1. Describe the fuse plug failure process over time, including likely minimum and maximum time to failure for each time step of the failure process. This information may be available in the fuse plug design and construction documentation.
2. Expand the Supplemental Major Rehabilitation Evaluation Report to include the sensitivity analysis referred to in the mid-review conference call response above.
3. Develop additional sensitivity analyses and risk assessments as necessary to address potential failure mode (PFM)-related impacts that may occur if the failure of the fuse plug is delayed.
4. Describe the timing of the construction of the curb that is proposed to increase freeboard. If the plan is to construct the curb as an emergency measure please describe the feasibility of such construction during a major flood event.

Final Panel Comment 2

The assumption that the alkali-aggregate reaction (AAR) increases normal stress on monolith contacts or other surfaces within the monoliths (and therefore adds to surface frictional resistance) is not supported by quantitative data.

Basis for Comment

Potential Failure Mode (PFM) 19A is dismissed because the AAR condition causes an increase in frictional strength along the joint, sufficiently counteracting any reduction in friction due to deterioration of the concrete at the construction joint. However, PFM 18B appears to be dismissed in part because the percentages of cross-sectional areas affected by AAR are not significant and also in part because instrumentation shows that the rate of expansion due to AAR appears to be slowing, as is typical of AAR examples in older projects. It is unclear why PFM 19A and PFM 18B were dismissed due to these conditions and effects, which seem to be somewhat in conflict with each other.

The Panel notes that PFM 19A, sliding on bad construction joint in Monolith 11 of the main dam, was eliminated from consideration in Chapter 5. The Panel finds that the information regarding this failure mode is not presented clearly. It appears that a portion of the deterministic factor of safety against sliding is based on AAR in the concrete. The assumption that AAR increases normal stress on vertical faces of monoliths or any other surfaces of potential movement within the monuments, thereby adding to the frictional resistance along these surfaces, may not be valid. In addition, calculations provided in Appendix H do not show the effect of seismic loading on Failure Mode 19A. Seismic loading is expected to lower the factor of safety of this joint against sliding. The Supplemental Major Rehabilitation Evaluation Report (MRER) provides no quantitative data to support this assumption. Section 1.3.1.3 of the report states the following:

“The concrete monoliths are not keyed along the vertical face between them, however, the stress caused by AAR provides a normal load and lateral friction resistance that aides in stability”. (Section 1.3.1.3, page 1-5)

In Section 5.3, the Supplemental MRER states the following:

“Sliding failure of monolith 11 due to deterioration of bad construction joint, PFM 19A, was eliminated from further consideration because the AAR condition is causing an increase in friction strength along the joint and sufficiently counteracts any reduction in friction due to the deterioration of the concrete at the joint”. (Section 5.3, page 5-4)

It is uncertain if AAR actually increases normal stress on any potential failure surfaces. AAR is a very slow reaction that results in development of pattern cracks. Because of the slow nature of the reaction and development of cracks, any residual stresses associated with concrete expansion are likely to dissipate with time.

If the stress on the bad construction joint in Monolith 11 is different than described in the

Supplemental MRER then the monolith could fail, resulting in loss of pool and potential impacts downstream. Since PFM 19A was dismissed, the impacts of this failure have not been determined and are not presented in the report.

Significance – High

The inability to confirm the AAR conditions and its applicability affects the overall safety of the project and may impact the elimination of a PFM or require additional mitigation measures at the main dam.

Recommendations for Resolution

1. Provide further clarification about the assumptions regarding AAR and its applicability to PFMs 19A and 18B.
2. Review the rationale for eliminating both PFMs 19A and 18B.
3. Determine the impact of seismic loading on PFM 19A.
4. Examine the downstream impact of PFM 19A (sliding failure of Monolith 11) for an appropriate range of pool elevations if any doubt regarding the assumptions made during the review process (items 2 and 4) exists.

Final Panel Comment 3

Several potential failure modes (PFMs) may have been dismissed prematurely, thereby potentially affecting project benefits.

Basis for Comment

PFMs 6, 8, and 10 lead to failure of the saddle dam and were dismissed as credible but not significant during expert elicitation meetings due to the baseline condition that a barrier wall will be installed (Table 5-2 of the Supplemental Major Rehabilitation Evaluation Report [MRER]). Since the barrier wall will not be installed, these PFMs can no longer be dismissed.

Construction of the proposed roller compacted concrete (RCC) berm is not expected to dramatically change the probability of occurrence of these failure modes, only the consequence of the failure. However, water trapped between the saddle dam and the RCC berm could increase the probability somewhat, while the increased flow length could decrease the probability somewhat.

The Panel understands that the RCC berm will prevent a catastrophic pool loss; however, if the saddle dam fails, pool will be lost to elevation 658 feet until a replacement structure can be completed. Figure 6-7 of the Supplemental MRER indicates an annual exceedance probability of an elevation 658 feet pool of slightly greater than 40 percent, while the probability of the reservoir reaching the level required for a planned breach of the fuse plug is less than 0.01 percent. Loss of the saddle dam will have economic and environmental impacts due to the loss of this flood storage. Economic impacts will derive from more frequent downstream flooding. Environmental impacts will result from discharges over the RCC berm into a valley that currently sees no discharge from the reservoir except in an extreme event leading to the planned breach of the fuse plug.

The Panel believes that these economic and environmental impacts may influence the choice between the current proposed RCC berm with soil fill (PFM 7C) and RCC berm with a fuse gate structure to approximately elevation 691.5 feet (PFM 7D). The Panel does not believe that these failure modes, with the RCC berm, result in an annual probability of failure or average incremental life loss above the tolerable risk guidelines. Since both alternatives 7C and 7D meet acceptable risk guidelines, the Panel believes that alternative 7D may be a better option due to the higher residual risk of alternative 7C when compared to alternative 7D.

Significance – Medium

The premature elimination of PFMs 6, 8, and 10 could affect which remediation alternative is selected and could therefore affect project benefits.

Recommendations for Resolution

1. Review PFM 6, 8, and 10 to determine if one or more should be more fully developed.

2. Recalculate as necessary the annual probability of failure, annual costs, and annual benefits of each remediation option (7B, 7C, and 7D).
3. Review the selected remediation alternative to determine the most appropriate remediation.
4. Review and, if necessary, revise the environmental documentation to reflect the results of recommendations 1 through 3.

Final Panel Comment 4

The system response probabilities for Potential Failure Modes (PFMs) 7A, 7B, 7C, and 7D and their relationship to PFM 7 are not clearly presented in the documentation, and the choice of PFM 7C over 7D is not fully supported.

Basis for Comment

The event tree for PFM 7 is presented in Figure 5-12 of the Supplemental Major Rehabilitation Evaluation Report (MRER). Total system response probabilities for PFMs 7A, 7B, 7C, and 7D for various pool elevations are provided in Appendix F; however, the event trees that led to these total system response probabilities are not provided. The event trees are also not provided in the working document (spreadsheet) provided by the U.S. Army Corps of Engineers (USACE) to Battelle after the mid-review teleconference with the Panel on September 5, 2013.

As shown in Figure 5-12, system response probabilities are primarily controlled by nodes 2 and 7. Plate G-14 shows open features greater than 24 inches on each side of the existing saddle dam; therefore, the Panel expects the probability of node 2 would be much greater without the barrier wall (PFM 7). Additionally, the Panel expects that node 7 is not applicable for PFMs 7B, 7C, and 7D.

The Panel agrees that the proposed roller compacted concrete (RCC) berm will prevent a catastrophic pool loss below an elevation of 658 feet and is not questioning the decrease in average incremental life loss. The relationship between PFM 7 and PFMs 7A through 7D is difficult to understand since PFM 7 is not shown on Figures 9-17 and 10-2 of the Supplemental MRER.

The Panel also agrees that the probability of failure will decrease for PFMs 7B, 7C, and 7D when compared to PFM 7A, since failure can occur only when the reservoir is above elevation 658 feet. The reduction in probability of failure between PFMs 7A and 7B is due to the difference in probability between all pool elevations and that of the pool being above elevation 658 feet. This change does not appear sufficient to result in a 2.5-order-of-magnitude reduction in the probability of failure between PFMs 7A and 7B. Likewise, the basis of the additional 2.5-order-of-magnitude reduction between PFMs 7B and 7C (5 orders of magnitude between PFMs 7A and 7C) is not obvious to the Panel. Without the event trees and associated percentages for these failure modes, the Panel cannot evaluate these decreases in probability of failure; however, the Panel is concerned that the actual probability of failure may be above tolerable risk guidelines for one or more of these failure modes.

Finally, the effect of water trapped between the RCC berm and the saddle dam on the saddle dam is not discussed. Since the likely outlet for water falling on this area will be down through the alluvium and into the bedrock, it would seem that the potential for piping of the saddle dam would increase with construction of the RCC berm without drains, which is the currently selected alternative. This potential should be reflected in the probability assigned to node 2. The Panel believes that the proposed RCC berm,

with or without soil fill, does not decrease the potential for seepage and piping of the existing saddle dam.

Significance – Medium

Inaccuracies or errors in the event trees could affect the probability of failure calculations and influence which remediation alternative is selected.

Recommendations for Resolution

1. Review the detailed event trees for PFMs 7A, 7B, 7C, and 7D to ensure that the system response probabilities for different reservoir elevations are appropriate.
2. Revise node probabilities as necessary based on the current RCC berm concept (i.e., no grouting or drains).
3. Recalculate as necessary the annual probability of failure, annual costs, and annual benefits for each of the remediation alternatives being considered.
4. Review and, if necessary, revise the Supplemental MRER to reflect the results of recommendations 1 through 3.

Final Panel Comment 5

Apparent discrepancies in different sets of the dam breach modeling information and inconsistencies in the level of detail between different analyses made it difficult to assess the dam breach model.

Basis for Comment

The dam breach modeling information initially provided to the Panel as part of their review was limited. Additional information was requested during the mid-review teleconference and subsequent information provided additional detail. However, when the additional background information was compared with the information in the Supplemental Major Rehabilitation Evaluation Report (MRER), some discrepancies were noted. For example, some of the breach parameters contained in the CISP Dam Break Analysis, H&H Methodology Report, March 2010 (Draft), are similar to, but do not match, those in the Supplemental MRER. If the discrepancies between the different sets of information were resolved or explained during the design and evaluation process, the resolutions or explanations were not provided to the Panel.

Furthermore, the description of the hydrologic methodology and evaluation contains a significant amount of detail, while the dam breach modeling does not seem to contain a similar level of detail. The dam breach modeling does not provide sufficient information for the Panel to reliably evaluate the dam breach modeling results and is the missing/weak piece of information connecting the incoming flood event through the breach process to the point of downstream flooding and the flood impact assessment.

Unless review of the information transfer path of the data analysis from the initial analyses to Chapter 6 of the Supplemental MRER results in unexplained discrepancies or results in changes to the analysis, the significance of this comment could be lower. If discrepancies are noted, the significance could be higher.

Of final note, Figure 6-19 shows the upper confidence curve and the 2013 pool curve intersect near the 1 percent return frequency event, which the Panel finds unusual.

Significance – Medium

Dam breach modeling parameters have not been fully or clearly described, which limits Panel's ability to analyze a potential flood event through the breach process.

Recommendations for Resolution

1. Review the information transfer path of the data analysis from the initial analyses to Chapter 6 of the Supplemental MRER to verify that information in the Supplemental MRER is complete and represents the most current information.
2. Revise Chapter 6 of the Supplemental MRER to include an expanded dam breach summary table that contains all primary breach parameters, including breach bottom elevation and breach side slopes.
3. Develop a summary table for the general dam failure /no dam failure breach

runs that is similar in format to Table 6-11 (Saddle Dam Breach with roller compacted concrete (RCC) berm in place). Include the new summary table in Chapter 6.

4. Describe the sensitivity analyses that were performed as part of the analysis (this item could primarily be an appendix).
5. Review the upper confidence curve versus the 2013 pool curve shown in Figure 6-19. (Note, given that based on other information it takes a much larger event to cause problems, this may not be a concern).

Final Panel Comment 6

The project documentation does not account for the possibility that additional seeps could develop in the groin area and impact the main dam embankment.

Basis for Comment

During the site visit, the Panel was informed by the U.S. Army Corps of Engineers (USACE) Project Delivery Team (PDT) that the grout curtain installed in the left-rim downstream groin area in 2008 to 2010 was not completely effective and that a water seep had already developed in the groin area. Section 1.4.2.4 of Appendix G (page 146) states:

“The presence of a persistent wet spot on the groin, especially after a grout line has been installed specifically to cut off seepage from the Left Abutment through the Groin into the Embankment means there is still a path in which water could attack the embankment”.

Additionally, Section 1.4.4.4 of Appendix G (page 164) states:

“These communications from the left rim grout line to the Groin grout line show the potential for flow paths around the left side of the future barrier wall. The paths could have direct contact with the embankment against the left abutment, which could provide a path for piping of the embankment.”

The Panel believes that once the seepage barrier is installed in the main embankment and the pool level is raised, water will tend to find new pathways through the left rim and may result in the development of additional seeps in the groin area.

Extreme flood events are expected to exacerbate this situation by creating new seeps, enlarging the size of the existing seeps, and increasing the amount of discharge. These seeps may impact the downstream side of the embankment, resulting in piping. A review of the Supplemental Major Rehabilitation Evaluation Report and Appendix G, specifically with regard to past grouting operations, suggests that a single grout curtain is not adequate in preventing seeps through well-developed, interconnected, and complex karst features.

The planned extension of the barrier wall into the left rim may lengthen the seepage path, but the effect of the proposed barrier wall on seeps in the groin area is difficult to predict. Potential Failure Mode 16 may not accurately capture the probability of seepage around the barrier wall on the left side of the embankment.

Significance – Medium

Seepage in the left-rim groin area may lead to piping of the main embankment, which will negate the objectives of the plan currently being implemented.

Recommendations for Resolution

1. Develop an event tree and system response probability for seepage around the left side of the barrier wall resulting in piping of the embankment.
2. If justified by the resulting probability of failure, evaluate the feasibility of an additional grout curtain in the groin area and verify its success in stopping the existing seep and minimizing the potential for future seeps by suitable tests and piezometer reactions.
3. If justified by the resulting probability of failure, evaluate the feasibility of extending the barrier wall through the left rim (i.e., wrapping around the embankment) to more completely isolate the embankment from seepage through the left rim.
4. Install additional piezometers on both sides of the groin grout curtain to monitor abnormal reactions and the potential for occurrence of additional seeps.

Final Panel Comment 7

The effects of climate change on the Probable Maximum Flood (PMF) and the magnitude of the reservoir elevation have not been evaluated.

Basis for Comment

While climate as part of the existing environment is discussed in the EA and Supplemental Major Rehabilitation Evaluation Report (MRER), the potential effects of climate change on the tentatively selected plan are not considered, including potential effects on the PMF and reservoir elevation. Documentation and guidance issued by the U.S. Army Corps of Engineers (USACE) over the past 3 years state the agency's intention to consider climate change as part of the planning process, as shown in the following excerpts:

"Climate change impacts affect water availability, water demand, water quality, stormwater and wastewater infrastructure, flood and coastal storm infrastructure, wildland fires, ecosystem functioning, coastal zone functioning, navigation, and energy production and demand. All of these factors affect the water resources projects operated by the Corps and its non-Federal sponsors. Many of these were designed and constructed before climate change was recognized as a potential influence.

"The entire portfolio of USACE Civil Works water resources infrastructure and programs, existing and proposed, could be affected by climate change and adaptation to climate change. This affects design and operational assumptions about resource supplies, system demands or performance requirements, and operational constraints. Both droughts and floods can affect the operations of these projects. Numerous regulatory decisions made by USACE will need to be informed by climate change impacts and adaptation considerations throughout the U.S., especially in western states." (USACE, 2013)

"In response to growing body of evidence about climate impacts to our missions and operations, we published a foundational report with other water resources agencies: *Climate Change and Water Resources Management: A Federal Perspective*. [¹] Since that time, we have developed a governance structure to support mainstreaming adaptation by establishing an overarching *USACE Climate Change Adaptation Policy Statement* and a Climate Change Adaptation Steering Council. This policy requires USACE to mainstream climate change adaptation in all activities to help enhance the resilience of our built and natural water-resource infrastructure and reduce its potential vulnerabilities to the effects of climate change and variability." (USACE, 2012b)

Significance – Medium

¹ Brekke et al., 2009 (also known as Circular 1331).

Without including a discussion of the potential effects of climate change in the documentation, the EA and the Supplemental MRER may not comply with the USACE climate change adaptation policy.

Recommendations for Resolution

1. Describe the potential effects of climate change on the tentatively selected plan, including an evaluation of the PMF and the magnitude of the reservoir elevation that would result.
2. Discuss how these potential effects of climate change were considered during plan formulation and development.
3. Revise the EA and the environmental summary in the Supplemental MRER to include this information.
4. Revise the probability of failure for each failure mode if the reservoir stage versus probability function changes as a result of new calculations considering climate change parameters.

Literature Cited:

Brekke, L.D., Kiang, J.E., Olsen, J.R., Pulwarty, R.S., Raff, D.A., Turnipseed, D.P., Webb, R.S., and White, K.D. (2009). Climate change and water resources management—A federal perspective: U.S. Geological Survey Circular 1331, 65 p. Available online at <http://pubs.usgs.gov/circ/1331/>.

USACE (2012b). Climate Change Adaptation Plan and Report. U.S. Army Corps of Engineers. June 2012.

USACE (2013). Responses to Climate Change. U.S. Army Corps of Engineers website dated January 14, 2013. Available at www.corpsclimate.us/. Accessed September 13, 2013.

Final Panel Comment 8

The assumption that upper and lower leaks in the right rim are primarily due to solution channels along the bedding planes is not valid.

Basis for Comment

The right rim karst features are considered less well-developed and less problematic than the left rim, and the upper and lower leaks in the right rim do not pose the threat of a catastrophic failure. Nevertheless, the assumption that the upper and lower leaks in the right rim are primarily due to solution channels along the bedding planes (Appendix G, Sections 1.4.2.5 and 1.4.2.6, pages 146-147) minimizes the complex and unpredictable nature of the karst in the right rim. Vertical joints, cross-cutting the bedding planes, are very prominent at the project site, and large solution channels have developed along these joints, as indicated by numerous photographs of core trench included in the Supplemental Major Rehabilitation Evaluation Report (MRER) and in Appendix G.

These joints were clearly visible in the right rim during the site visit. In most geologic situations, water enters the bedding planes through cross-cutting joints. Under an extreme future event, water flow along vertical joints in the right rim can result in rapid and uncontrollable increases in flows from the upper and lower leaks.

Significance – Medium

A more complete discussion of the nature of the flow in the right rim, including the significance of vertical joints, will add to the completeness of the Supplemental MRER and provide a valuable resource to understanding the future increases in the upper and lower leaks.

Recommendations for Resolution

1. Revise the text in the Supplemental MRER and Appendix G to remove the assertion that right rim flow occurs primarily due to solution channels along the bedding planes.
2. Continually monitor the right rim seeps.
3. Evaluate the role of vertical joints in contributing to right abutment leaks.

Final Panel Comment 9

Several topics customarily addressed to comply with the National Environmental Policy Act (NEPA) either are not discussed in the project documentation or received minimal discussion, and some sections of the environmental assessment (EA) refer to measures that are no longer part of the tentatively selected plan.

Basis for Comment

The following topics require revision or were excluded from the NEPA documentation:

- NEPA documentation typically includes a brief summary of public involvement activities. A great deal of public outreach has been performed for the Center Hill Dam, either in concert with NEPA documentation for other projects or as part of the dam safety program. A summary of this outreach is not included in the project documentation and may be viewed as having been overlooked.
- Short-term, temporary environmental effects and potential mitigation measures associated with construction are given little attention. In particular, short-term impacts on noise, air quality, water quality, migratory birds, fisheries, and traffic during construction have not been adequately addressed.

The following topics require revision or were excluded from the EA, the Supplemental Major Rehabilitation Evaluation Report (MRER), or the biological assessment (BA):

- Several measures as part of the proposed alternative discussed in the EA (i.e., sinkhole repairs, left rim stabilization, dam safety clearing, and weir repairs) have incomplete descriptions, lack summaries of environmental effects, or are no longer considered part of the tentatively selected plan.
- At least one karst formation in Tennessee (Snail Shell Cave) supports federally- or state-listed karst species. These species are not discussed in the EA or the BA.

Significance – Low

The exclusion or minimization of some topics affects the completeness of the project documentation, and discussions of measures that are no longer part of the tentatively selected plan affect documentation quality.

Recommendations for Resolution

1. Revise the EA and the environmental summary in the Supplemental MRER to eliminate discussion of or reference to those measures that are no longer part of the tentatively selected plan.
2. Revise incomplete sections in the EA and the environmental summary in the Supplemental MRER to describe and analyze the effects of any unaddressed measures that are still part of the tentatively selected plan.
3. Include a brief summary of public outreach activities that have been performed for the Center Hill Dam over the past several years.

4. Briefly expand the discussion, in one short section, of the short-term effects of project construction, specifically the short-term, temporary impacts on noise, air quality, water quality, migratory birds, fisheries, and traffic. Include any potential mitigation measures (e.g., timing of construction activities).
5. Briefly discuss in the EA and BA whether surveys for karst species were performed. If not, include a rationale that supports a conclusion that they would not be found in the project area.

Final Panel Comment 10

It is unclear whether the economic analysis has taken into consideration the annualized benefits of power and water supply from the Center Hill Dam in relation to the annualized cost of the most likely alternative.

Basis for Comment

U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1105-2-100 notes that annualized benefits of the federal water supply plan are equal to the annualized costs of the most likely alternative (USACE, 2000). This method of analysis could impact the economic analysis.

As presented in Section 8.3.3 of the Supplemental Major Rehabilitation Evaluation Report (MRER), the lost benefits appear to be determined from an accounting procedure predicated on project benefits lost in the event of a failure. The power and water supply benefits are based on payment agreements and not on substitution costs incurred by the consumer.

In any case, the Panel recognizes that protection of life takes precedence over economic benefits in the effort to remediate Center Hill Dam to a lower dam safety action classification.

Significance – Low

Presenting the basis for using payment agreements instead of the costs incurred by the consumer for alternative water and power supply would provide clarification to the report.

Recommendations for Resolution

1. Provide the basis for using payment agreements to calculate lost benefits rather than the costs incurred by the end users.
2. If the change in costs to the user is the proper metric, provide text clearly stating this basis and revise the benefit analysis.

Literature Cited:

USACE (2000). Planning Guidance Notebook. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Regulation (ER) No. 1105-2-100. April 22.

Final Panel Comment 11

It is not clear what approach will be used to cap or restore an area of hazardous materials that leached from treated timber formerly stored on the site.

Basis for Comment

Section 3.16 of the environmental assessment (EA) states that the U.S. Army Corps of Engineers (USACE) has recommended capping and covering the former location of treated timber piles. The EA also suggests that this relatively flat area may be able to serve as an equipment and aggregate soils storage or “laydown” area.

The EA further indicates that there is an ongoing discussion with the State of Tennessee regarding these plans, and that the USACE recommendation as described in the EA may not be implemented. During the site visit, the Project Delivery Team (PDT) indicated that the State may not be in agreement with the cap-and-cover remedy. The Panel was unable to evaluate remedial plans for the former timber pile location due to uncertainty with regard to the USACE recommendation.

Significance – Low

Uncertainty regarding the remedial approach that will be used for the former timber pile location affects the completeness of the document.

Recommendations for Resolution

1. Develop the selected remedial approach or a set of reasonable alternative approaches.
2. Revise the EA to describe the remedial approach or the suite of choices being considered, along with their potential effects.

Final Panel Comment 12

A detailed correlation between discontinuity orientations and known seepage pathways (karst features) has not been established.

Basis for Comment

As acknowledged by the USACE Project Delivery Team (PDT), the main problem at the Center Hill Dam site is the presence of subsurface karst features which serve as pathways for seepage of lake water through foundation and abutments. This seepage results in piping, uplift, instability, and water loss. The success of the tentatively selected plan depends on the extent to which the karst features, and their interconnections, have been adequately identified and delineated. The review documents describe how historic photos, subsurface drilling, multiple grouting operations, dye tests, and sinkhole and spring locations were used to characterize and map karst features and how many of these features, and their interconnections, follow the existing discontinuities.

However, the documents do not provide a detailed correlation between orientations of individual discontinuities and development of the karst features. For example, neither the Supplemental Major Rehabilitation Evaluation Report nor Appendix G (Section 1.1.3, pages 14-23) fully explains:

- how many principal joint sets are present in the Cannon, Catheys, and Hermitage Formations with solution channels,
- what are their specific orientations, and
- which of these orientations preferentially favor karst development, or is the karst development generally random.

A clear description of the correlation between discontinuity orientations and karst development will help in optimizing future grouting programs (if they become necessary), understanding post-rehabilitation seeps/springs, selecting the appropriate locations for additional piezometers, and interpreting the piezometric data.

Significance – Low

A better description of the relationship between discontinuity orientation, geologic formation, and known seepage pathways will improve the understanding of the success of the rehabilitation efforts.

Recommendations for Resolution

1. Plot all available discontinuity orientation data, including bedding, on a stereonet and determine the most prominent orientations (principal joint sets). This may require the plotting of 200 to 500 discontinuity orientations, depending upon the variability of orientation data. The “Dips” software program (Rocscience, 2013), or other available software, can be used to perform this analysis very quickly.
2. Plot all known orientations of karst features (seepage paths, caves, cavities) on a stereonet and determine orientations of these features.

3. Compare the principal orientations from recommendations 1 and 2, and identify the orientations that preferentially favor karst development.

Literature Cited:

Rocscience (2013). Dips - Graphical and Statistical Analysis of Orientation Data, version 6.0. Rocscience Inc. - Software Tools for Soil and Rock, University of Toronto, Canada.

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APPENDIX B

**Final Charge to the Independent External Peer Review Panel
as Submitted to USACE on August 15, 2013**

on the

Center Hill Dam Supplemental MRER

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**Charge Questions and Guidance to the Peer Reviewers
for the
Independent External Peer Review of the Supplemental Major Rehabilitation Evaluation
Report for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee**

BACKGROUND

Center Hill Dam is currently a USACE Dam Safety Action Classification I (DSAC I) dam in DeKalb County, Tennessee. A Major Rehabilitation Evaluation Report (MRER) was approved in 2006 and construction began in 2008. A baseline risk assessment (RA) was done in 2010 through 2012 to document post construction risks for elements already completed or in construction. The RA incorporates both new data (subsurface exploration obtained during construction) and risk informed policies and procedures implemented after the original report was approved. Resulting rehabilitation scope changes include a reduction in barrier wall and grouting and the construction of a Roller Compacted Concrete (RCC) Reinforcing Berm at the Saddle Dam (in lieu of a barrier wall and grout curtain). The Supplemental MRER includes the risk assessment and documents changes to the project scope including NEPA documentation and a Real Estate Plan.

The Supplemental MRER was conducted in accordance with USACE Engineering Regulation, ER 1110-2-1156, Dam Safety Policy and Procedures. Since Center Hill is a DSAC I Dam, in coordination with the Corps' Lakes and Rivers Division, USACE Headquarters, and Risk Management Center Director, the Nashville District has continued design of the RCC Berm at the Saddle Dam concurrent with processing and approval of the Supplement. This will hasten the construction of the final protective measures and minimize project cost increases and schedule delays. Since the saddle dam RCC berm is already in the design phase a Type II IEPR (Safety Assurance Review (SAR)) is also underway.

Study Description

Center Hill Reservoir is about 50 miles east of Nashville, Tennessee and about 7 miles south of Interstate 40. The dam is in north central DeKalb County, Tennessee. It impounds the Caney Fork River, a tributary of the Cumberland River, 26.6 river miles upstream of their confluence. The total Center Hill drainage area is 2,174 square miles. The average slope of the reservoir is over three feet per mile, causing the 18,000-acre lake to be prone to rapid water-level rises. The total storage area exceeds two million acre-feet. It provides flood risk reduction, navigation, hydropower, recreation, water supply and water quality benefits. It contains three hydropower units with a combined capacity of 135,000 kilowatts.

The Center Hill project was authorized by the United States Congress in the Flood Control Act approved on June 28, 1938 (Public No. 761, 75th Congress, 3rd session). Construction began in January 1942, but was suspended a year later for the duration of World War II. Construction resumed in 1946 and the project was fully operational in 1951.

Center Hill Dam is a 248-foot high combination concrete-earthen embankment dam with foundation seepage issues stemming from original construction flaws. The embankment portion of the dam was placed directly on a mature karst limestone with little to no foundation treatment.

Outside the narrow core trench, existing alluvial and residual soils were left in place. Further adding to the risk are solution-widened joint sets that are parallel and perpendicular to the dam.

The main components of the 2006-approved MRER remediation plan are: 1) comprehensive foundation grouting and 2) concrete cutoff walls into the foundation of the main dam and saddle dam embankments. The first major construction was the 2008-2010 grouting of the main dam embankment, the groin area and the left rim. A barrier wall contract was awarded in 2011 for the main dam embankment.

The new risk assessment confirmed that the project is vulnerable to seepage and piping failure of the main dam embankment (grout curtain complete and barrier wall currently under construction) and saddle dam. The cave and sinkhole treatments on the left rim and additional grout curtains under the concrete section and right rim are no longer deemed necessary. In addition, the risk assessment identified overtopping of the saddle dam as a possible hazard. Constructing a stability berm that can be over topped addresses both the seepage and overtopping failure modes. For the current recommendation, an EA (Supplement 3) is complete, and a FONSI is anticipated. Real Estate interests are needed for the RCC Berm construction. A land exchange of 3.47 acres with the State of Tennessee is planned, as well as Temporary Work Area Easement and a permanent access easement.

OBJECTIVES

The objective of this work is to conduct an independent external peer review (IEPR) of the technical basis for the economic, engineering, and environmental methods, models, data, analyses, and assumptions supporting the Supplemental Major Rehabilitation Evaluation Report for Center Hill Dam, Caney Fork River, DeKalb County, Tennessee (hereinafter: Center Hill Dam IEPR). Peer review is one of the important procedures used to ensure that the quality of published information meets the standards of the scientific and technical community. Peer review typically evaluates the clarity of hypotheses, validity of the research design, quality of data collection procedures, robustness of the methods employed, appropriateness of the methods for the hypotheses being tested, extent to which the conclusions follow from the analysis, and strengths and limitations of the overall product.

The purpose of the IEPR is to assess the “adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used” (EC 1165-2-214; p. D-4) for the Center Hill Dam documents. The IEPR will be limited to technical review and will not involve policy review. The IEPR will be conducted by subject matter experts (i.e., IEPR panel members) with extensive experience in geotechnical engineering, engineering geology, economics/planning, environmental planning/NEPA and hydraulic and hydrology (H&H) engineering issues relevant to the project. They will also have experience applying their subject matter expertise to dam safety management.

The experts will be “charged” with responding to specific technical questions, as well as providing a broad technical (engineering, economic, and environmental) evaluation of the overall project. The review panel shall focus on answering the general questions listed in Appendix B. The review panel shall not make a recommendation on whether a particular alternative should be

implemented, as the Chief of Engineers is ultimately responsible for the final decision on USACE work products.

The IEPR panel members (i.e., reviewers) will identify, recommend, and comment upon the assumptions underlying the analyses as well as evaluating the soundness of models, and the design and analytical methods utilized. The reviewers should be able to evaluate whether the interpretations of analyses and conclusions are technically sound and reasonable, provide effective review in terms of both usefulness of results and of credibility, and have the flexibility to bring important issues to the attention of decision makers. The reviewers may offer opinions as to whether there are sufficient technical analyses upon which to base the ability to implement the recommendations of the Center Hill Dam Supplemental MRER. The independent reviewers will address factual inputs, data, the use geotechnical, structural, hydrologic, and hydraulic models, analyses, assumptions, and other scientific and engineering tools/methodologies to inform decision-making process. This work will be conducted in accordance with procedures described in the Department of the Army, U.S. Army Corps of Engineers, Engineer Circular (EC) 1165-2-214, *Civil Works Review* (15 December 2012), and the Office of Management and Budget's *Final Information Quality Bulletin for Peer Review* (16 December 2004).

USACE officials may attend panel meetings, but may not participate in the management or control of the group. USACE cannot be a voting member of the group, may not direct activities at the meetings, and may not develop the agenda for the meetings. USACE officials must refrain from participating in the development of any reports or final work product of the group.

DOCUMENTS PROVIDED

The following is a list of documents, supporting information, and reference materials that will be provided for the review.

Documents for Review

The following documents are to be reviewed by designated discipline:

Title	Approx. No. of Pages	Required Disciplines
Center Hill Dam Supplemental Major Rehabilitation and Evaluation Report	192	All Disciplines
Appendix A – References	4	All Disciplines
Appendix B – PFMA Documentation	29	All Disciplines
Appendix C – Initiating Events	27	H&H Engineer
Appendix D – System Response	6	Geotechnical Engineer, Engineering Geologist, H&H Engineer
Appendix E – Consequence Documentation	16	All Disciplines
Appendix F – Risk Engine Results	27	Geotechnical Engineer, Engineering Geologist, H&H Engineer
Appendix G – Pertinent Project Data Used in Risk Estimates	267	Geotechnical Engineer, Engineering Geologist, H&H Engineer
Appendix H – Saddle Dam Stability Calculations	23	Geotechnical Engineer, Engineering Geologist, H&H Engineer
Appendix I – Environmental Compliance	196	Environmental Planner/NEPA
Appendix J – Real Estate	17	Economics/Planner, Environmental Planner/NEPA
Appendix K – Cost Estimating	41	Economics/Planner
Appendix L – Potential Failure Mode Illustrations	7	Geotechnical Engineer, Engineering Geologist, H&H Engineer
Total Page Count	852	

Supporting Information

- Seepage Control Major Rehabilitation and Evaluation Report (2006 Report, 87 pages)

Documents for Reference

The following USACE regulations shall be followed in conducting the IEPR. The most recent Engineer Circulars (EC), Manuals (EM), Pamphlets (EP), and Regulations (ER) shall be used,

which are available at: <http://140.194.76.129/publications/> or <http://www.hnd.usace.army.mil/techinfo/engpubs.htm>.

General

- EC 1105-2-410, Review of Decision Documents, 22 August 2008
- EC 1105-2-412, Assuring Quality of Planning Models, 31 March 2011
- EC 1165-2-214, Water Resources Policies and Authorities - Civil Works Review, 15 December 2012
- EC 1165-2-210, Water Resources Policies and Authorities - Water Supply Storage and Risk Reduction Measures for Dams, 9 April 2010
- EP 1110-2-13, Dam Safety Preparedness, 28 June 1996
- ER 1110-1-12, Engineering and Design - Quality Management, 31 March 2011 (change 2)
- ER 1110-2-1150, Engineering and Design - Engineering and Design for Civil Works Projects, 31 August 1999
- ER 1110-2-1155, Engineering and Design - Dam Safety Assurance Program, 12 September 1997
- ER 1110-2-1156, Engineering and Design - Safety of Dams - Policy and Procedures, 28 October 2011
- ER 1110-1-8159, Engineering and Design - DrChecks, 10 May 2001.
- National Academy of Sciences, "Policy and Procedures on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports," May 2003 for General Scientific and Technical Studies and Assistance: General Scientific and Technical Studies and Assistance. Available at: <http://www.nationalacademies.org/coi/index.html>
- Water Resources Development Act of 2007, Sections 2034 & 2035, Pub. L. 110-114. Privacy Act, 5 U.S.C. § 522a as amended.

Environmental/Planning

- ER 1105-2-100, Guidance for Conducting Civil Works Planning Studies. CECW-P, 28 December 1990
- Council on Environmental Quality. 1978. Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act. 40 CFR Parts 1500-1508. Washington, DC: U.S. Government Printing Office (November 29, 1978).
- ER 200-2-2, Environmental Quality, Procedures for Implementing NEPA. CECWRE (now CECW-A), 4 March 1988.

Engineering Geology

- EM 1110-1-1804, Engineering and Design - Geotechnical Investigations, 01 January 2001
- ER 1110-1-1807, Engineering and Design - Procedures for Drilling in Earth Embankments, 01 March 2006

- EM 1110-1-1802, Geophysical Exploration for Engineering and Environmental Investigations, 31 August 1995.

Geotechnical Engineering

- EM 1110-2-1901, Engineering and Design - Seepage Analysis and Control for Dams, 30 April 1993
- EM 1110-2-1902, Engineering and Design - Slope Stability, 31 October 2003
- EM 1110-2-2300, Engineering and Design - General Design and Construction Considerations For Earth and Rock-Fill Dams, 30 July 2004
- EM 1110-2-1908, Engineering and Design - Instrumentation of Embankment Dams and Levees, 30 June 1995
- ER 1110-2-110, Engineering and Design - Instrumentation for Safety Evaluations of Civil Works Projects, 8 July 1985.

Materials Engineering

- ER 1110-1-1901, Project Geotechnical and Concrete Materials Completion Report for Major USACE Project, 22 February 1999
- EM 1110-2-1906, Laboratory Soils Testing, 20 August 1986
- ER 1110-2-1911, Engineering and Design - Construction Control for Earth and Rock-Fill Dams, 30 September 1995
- EM 1110-2-2000, Engineering and Design - Standard Practice for Concrete for Civil Works Structures, 31 March 2001.

Structural Engineering

- EM 1110-2-2002, Evaluation and Repair of Concrete Structures, 30 June 1995
- EM 1110-2-2100, Engineering and Design - Stability Analysis of Concrete Structures, 1 December 2005
- EM 1110-2-2102, Waterstops and Other Preformed Joint Materials for Civil Works Structures, 30 September 1995
- EM 1110-2-2104, Engineering and Design - Strength Design for Reinforced-Concrete Hydraulic Structures, 20 August 2003
- EM 1110-2-2400, Engineering and Design - Structural Design and Evaluation of Outlet Works, 02 June 2003
- EM 1110-2-4300, Instrumentation for Concrete Structures, 30 November 1987
- ER 1110-2-100, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures, 15 February 1995.

Hydraulic Engineering

- EM 1110-2-1602, Engineering and Design - Hydraulic Design of Reservoir Outlet Works, 15 October 1980

- EM 1110-2-1603, Engineering and Design - Hydraulic Design of Spillways, 16 January 1990
- EM 1110-2-2902, Engineering and Design - Conduits, Culverts, and Pipes, 31 March 1998
- EM 1110-2-3600, Engineering and Design - Management of Water Control Systems, 30 November 1987
- ER 1110-8-2 (FR), Inflow Design Floods for Dams and Reservoirs, 1 March 1991
- ER 1110-2-240, Water Control Management, 8 October 1998
- ER 1130-2-530, Flood Control Operations and Maintenance Policies, 30 October 1996
- ER 1110-2-8156, Preparation of Water Control Manuals, 31 August 1995.

SCHEDULE

This schedule is based on the August 9, 2013 receipt of the final review documents. The schedule will be revised upon receipt of final review documents.

Task	Action	Due Date
Conduct Peer Review	Battelle sends review documents to panel members	8/19/2013
	Battelle convenes kick-off meeting with panel members	8/20/2013
	Battelle convenes kick-off meeting with USACE and panel members	8/23/2013
	Battelle convenes site visit for panel members to view project specific locations	8/23/2013
	Battelle convenes mid-review teleconference for panel members to ask clarifying questions of USACE	8/28/2013
	Panel members complete their individual reviews	9/3/2013
Prepare Final Panel Comments and Final IEPR Report	Battelle provides panel members with talking points for Panel Review Teleconference	9/5/2013
	Battelle convenes Panel Review Teleconference	9/5/2013
	Battelle provides Final Panel Comment templates and instructions to panel members	9/6/2013
	Panel members provide draft Final Panel Comments to Battelle	9/11/2013
	Battelle provides feedback to panel members on draft Final Panel Comments; panel members revise Final Panel Comments	9/11-9/17/13
	Battelle finalizes Final Panel Comments	9/17/2013
	Battelle provides Final IEPR Report to panel members for review	9/19/2013
	Panel members provide comments on Final IEPR Report	9/23/2013
	*Battelle submits Final IEPR Report to USACE	9/25/2013

Task	Action	Due Date
Comment/ Response Process	Battelle inputs Final Panel Comments to DrChecks and provides Final Panel Comment response template to USACE	9/25/2013
	Battelle convenes teleconference with Panel to review the Post-Final Panel Comment Response Process (if necessary)	9/27/2013
	USACE provides draft PDT Evaluator Responses to Battelle	10/2/2013
	Battelle provides the panel members the draft PDT Evaluator Responses	10/3/2013
	Panel members provide Battelle with draft BackCheck Responses	10/7/2013
	Battelle convenes teleconference with panel members to discuss draft BackCheck Responses	10/8/2013
	Battelle convenes Comment-Response Teleconference with panel members and USACE	10/9/2013
	USACE inputs final PDT Evaluator Responses to DrChecks	10/11/2013
	Battelle provides final PDT Evaluator Responses to panel members	10/15/2013
	Panel members provide Battelle with final BackCheck Responses	10/17/2013
	Battelle inputs the panel members' final BackCheck Responses to DrChecks	10/18/2013
	*Battelle submits pdf printout of DrChecks project file	10/18/2013

CHARGE FOR PEER REVIEW

Members of this IEPR Panel are asked to determine whether the technical approach and scientific rationale presented in the Center Hill Dam documents are credible and whether the conclusions are valid. The Panel is asked to determine whether the technical work is adequate, competently performed, properly documented, satisfies established quality requirements, and yields scientifically credible conclusions. The Panel is being asked to provide feedback on the economic, engineering, environmental resources, and plan formulation. The panel members are not being asked whether they would have conducted the work in a similar manner.

Specific questions for the Panel (by report section or Appendix) are included in the general charge guidance, which is provided below.

General Charge Guidance

Please answer the scientific and technical questions listed below and conduct a broad overview of the Center Hill Dam documents. Please focus your review on the review materials assigned to your discipline/area of expertise and technical knowledge. Even though there are some sections with no questions associated with them, that does not mean that you cannot comment on them. Please feel free to make any relevant and appropriate comment on any of the sections and appendices you were asked to review. In addition, please note the following guidance. Note that

the Panel will be asked to provide an overall statement related to 2 and 3 below per USACE guidance (EC 1165-2-214; Appendix D).

1. Your response to the charge questions should not be limited to a “yes” or “no.” Please provide complete answers to fully explain your response.
2. Assess the adequacy and acceptability of the engineering, economic and environmental assumptions and projections, project evaluation data, and any biological opinions of the project study.
3. Assess the adequacy and acceptability of the economic analyses, environmental analyses, engineering analyses, formulation of alternative plans, methods for integrating risk and uncertainty, and models used in evaluating economic or environmental impacts of the proposed project.
4. If appropriate, offer opinions as to whether there are sufficient analyses upon which to base a recommendation.
5. Identify, explain, and comment upon assumptions that underlie all the analyses, as well as evaluate the soundness of models, surveys, investigations, and methods.
6. Evaluate whether the interpretations of analysis and the conclusions based on analysis are reasonable
7. Please focus the review on assumptions, data, methods, and models.

Please **do not** make recommendations on whether a particular alternative should be implemented, or whether you would have conducted the work in a similar manner. Also please **do not** comment on or make recommendations on policy issues and decision making. Comments should be provided based on your professional judgment, **not** the legality of the document.

1. If desired, panel members can contact one another. However, panel members **should not** contact anyone who is or was involved in the project, prepared the subject documents, or was part of the USACE Agency Technical Review (ATR).
2. Please contact the Battelle Project Manager (Lynn McLeod, mcleod@battelle.org) or Deputy Program Manager (Rachel Sell, sellr@battelle.org) for requests or additional information.
3. In case of media contact, notify the Battelle Program Manager, Karen Johnson-Young (johnson-youngk@battelle.org) immediately.
4. Your name will appear as one of the panel members in the peer review. Your comments will be included in the Final IEPR Report, but will remain anonymous.

Please submit your comments in electronic form to Lynn McLeod, mcleod@battelle.org, no later than September 3, 2013, 10 pm ET.

**Independent External Peer Review
of the
Supplemental Major Rehabilitation Evaluation Report for Center Hill Dam, Caney Fork
River, DeKalb County, Tennessee**

Charge Questions as Supplied by USACE

General (4)

1. Are the engineering and environmental methods, models, analyses used adequate and acceptable?
2. Were risk and uncertainty sufficiently considered?
3. In your opinion, are there any other issues, resources, or concerns that have not been identified and/or addressed?
4. In your opinion, were there sufficient analyses upon which to base the recommendation?

Existing and Future Without Project Resources (3)

5. Are the assumptions used as the basis for developing the most probable future without project conditions reasonable?
6. Were adequate scenarios effectively considered (applied during analyses where relevant and/or reasonably investigated)?
7. Were the potential effects of climate change addressed?

Plan Formulation / Evaluation (2)

8. Was a reasonably complete array of possible measures, including single objective and multi-objective measures, adequately considered in the development of alternatives?
9. Were the engineering, economic, and environmental analyses used for this study consistent with generally accepted methodologies? Why or why not?

Recommended Plan (1)

10. Please comment on the completeness of the recommended plan, i.e. will any additional efforts, measures, or projects be needed to realize the expected benefits?

Environmental Consequences (1)

11. Are the scope and detail of the potential adverse effects that may arise as a result of project implementation sufficiently described and supported?

Mitigation (1)

12. Are mitigation measures adequately described and discussed? If not, please explain.

Dam Safety (4)

13. Has the condition of the dam; including the design and construction of the dam and appurtenant features, project maintenance, previous major rehabilitations and dam safety modifications, and the dam's performance over time, been adequately described with regards to:
 - the risk to the structure?
 - the economic impacts, environmental impacts, and life safety consequences posed by the structure?
 - the benefits provided by the structure?
14. Have all characteristics, conditions, and scenarios leading to failure, along with the potential consequences, been identified and described?
15. Have all pertinent factors, including population at risk, been considered in the estimation of risk for the baseline condition?
16. Has anything significant been overlooked in the development of the assessment of this structure or the alternatives?

Summary Questions (developed by Battelle)

17. Please identify the most critical concerns (up to 5) you have with the project and/or review documents. These concerns can be (but do not need to be) new ideas or issues that have not been raised previously.
18. Please provide positive feedback on the project and/or review documents.